JUN 27

METALS & ALLOYS

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The Magazine of Metallurgical Engineering

INCLUDING
CURRENT METALLURGICAL ABSTRACTS

SLAG DUMP AT COPPER CLIFF, ONTARIO (*Courtesy International Nickel Co., of Canada, Ltd.*)

VOLUME 4 — **JUNE 1933** — NUMBER 6

HIGHLIGHTS by H. W. GILLETT
PAGE A9

CORROSION AND HEAT MEET THEIR MATCH IN ENDURO

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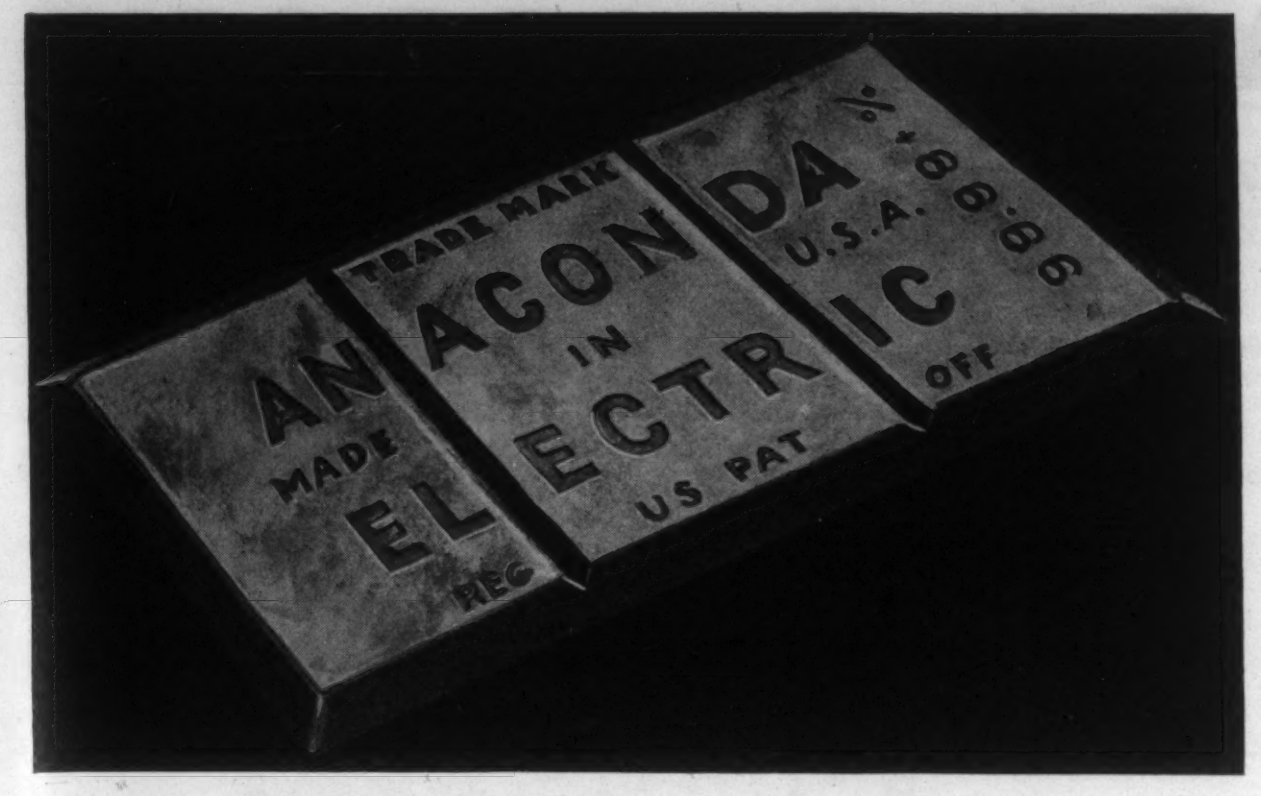

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HIGHLIGHTS by H. W. GILLETT

DO YOU want to know what metallurgical engineers are saying, the world over? Look in the Current Metallurgical Abstracts. Here are some of the points covered by authors whose articles are abstracted in this issue.

How would you test wire rope? . . . rails? Fatigue testing (de Forest & Hopkins, page MA 175 L1) and reversed torsion testing (Forcella, page MA 175 L3) are advocated for evaluation of wire rope. Forcella (page MA 175 L5) also advocates repeated impact tests for evaluating quality of rails, citing experience of the Italian railways.

Hot Galvanizing and endurance. Hot galvanizing, according to Bureau of Standards' (page MA 175 L6) experiments adversely affects the endurance of hard, heat-treated steels.

Compression Fatigue. According to Thomas & Lowther (page MA 175 L9) fatigue occurs in repeated compression even when no tensile stress is involved in the stress reversal.

"Accelerated endurance tests valueless. Schulz and Buchholtz (page MA 175 L 8) point out that "accelerated" endurance tests are valueless, thus agreeing with American opinion. It is helpful to have these German authorities make this statement, for some German endurance machines are designed for "accelerated" tests and a good many such tests are recorded in German publications.

Bearing capacity decreases with increased R. P. M., according to Heldt (page MA 177 L4) because of the effect upon the oil of the heat generated.

Life of Aircraft Engines increased. Metallurgical and designing engineers have increased the flying hours in the life of aircraft engines from 80 to 1500 hrs. (Deuble, page MA 178 R8.)

Cast iron or welded steel roads for Germany are discussed by three different authors (Brunner, page MA 177 L2; Becker and Leitolf, page MA 177 R8.) (See also *Engineering News Record,* page MA 178 L8.)

Aluminum foil as heat insulator, such as is now used in one of the best known electric refrigerators, is discussed by Gregg (page MA 177 R7.)

Steels for high pressure and temperature. Lupberger (page MA 177 R9) advocates C-Mo and Cr-Mo steels for high-pressure, high-temperature service in boilers.

Non-Ferrous Alloy. A Si-Zn-Cu alloy, equivalent to Cu in corrosion resistance and suitable for thin-walled castings, is mentioned by Becker (page MA 178 R6).

What use Gallium? Gallium finds industrial uses, says Herzog (page MA 177 R5).

Aluminum Fire Department Ladders. The coils for high frequency electric furnaces can be more closely spaced when Al is used and insulated with an anodic coating according to a German publication (page MA 178 L4) devoted to boosting aluminum. But won't the tubing itself take enough more space than Cu, to make up the difference? However the anodic coating, which increases the rate of emission of heat and the high thermal conductivity of Al are said to make anodic coated Al just the thing for fire department ladders (page MA 178 L2).

Beryllium Alloys get more notice, in two abstracts (page MA 178 L5).

Aircraft Valve Steels. French standards for aircraft valve steels are issued (page MA 178 R2).

High Speed Steels. The high-carbon high-vanadium high-speed tool steels get German comment (page MA 178 R4). Use of Co in such steels is mentioned.

And still more Aluminum Alloys. Both German (page MA 178 L10) and French (page MA 178 R2) publications credit aluminum in railway cars with operating efficiency, due to lower weight, sufficient to make them economical. "65 Al casting and 25 Al forging alloys are on the market."

Welding 1% Mn, 0.8% Si, 0.3% Cu structural steel (St. 52) is evidently getting common in Germany, for Küchler (page MA 180 R4) discussed how to weld it, while Sommer (page MA 181 R2) mentions other types of St. 52 with Cr and Mo as well.

Improved castings of copper alloys are claimed for three methods, chill castings, centrifugal castings (both Becker, page MA 183 L1) and press castings (Mehrtens, page MA 183 L6).

"Blowy" ingots of 70:30 brass and bad surfaces from checked cast iron ingot molds are avoided by the use of copper molds, says Bailey (page MA 184 R1).

Twelve Roll Cluster Mill. Two tiny rolls, backed up by 10 other rolls in a German cluster mill, take as large reductions in two passes as a 6 roll mill does in five, and softer rolls stand up in it as well as harder ones in the 6 roll (Rohn, page MA 185 L5).

Chilled Rolls. Ho (page MA 184 R4) uses a Ni-Cr cast iron, high in alloys for the chilled working surface of a composite roll, while Taniguchi (page MA 186 L 2) uses the same alloying elements in large chilled rolls, but in much smaller amount.

Lead in Cast Iron. Bading, Scheil & Schulz (page MA 195 R2) find that addition of lead to cast iron has much the same effect on graphite nuclei as superheating does.

Hardening Babbitt without increased brittleness. Snelling (page MA 195 L4) claims that Bi up to ¼% hardens babbitt metal without making it brittle, and that it improves the frictional properties.

Active Carbon in Flotation. Braunstein (page MA 201 R4) suggests that active carbon may have a place in flotation of lead and zinc ores, since in very small amounts it hinders flotation of the gangue and makes for a cleaner separation.

Books. The reviewers liked some of the books. Hedges on Protective Films (page MA 169 L7) on Metals is informative and thought-provoking for those interested in corrosion. For metallographers, new editions of Goerens "Einführung" (page MA 172 L1), Garre's smaller "Einführung" (page MA 171 L6) and Greaves & Wrighton's "Microscopical Metallurgy" (page MA 172 L4) all good, are available. For the X-ray crystal structure man there are Clark's "Applied X-Rays" (page MA 173 L1)—perhaps over enthusiastic, but the most extensive account available in English, and von Hevesy's "Chemical Analysis by X-Rays" (page MA 174 L1), which is authoritative and unbiased. In fact the reviewer thinks that one could start from scratch, with no knowledge of the subject and make successful X-ray analyses just from studying this book alone. Sounds as though it were worth $3.00 all right. A more specialized book in this field is Schiebold's "Die Lauemethode" (page MA 174 L5), which assumes that the reader knows a lot before taking up the book.

Sulphur printing which shows up S only, not P, is discussed by Katzowna (page MA 172 L5).

Does Gallium mix with Mercury? Wouldn't you suppose that liquid Ga would mix with liquid Hg? Not so, say Puschin and co-workers (page MA 171 L7). They form two immiscible layers.

Pipe Corrosion, inside and outside, comes in for a lot of attention from Allyne, Blackall (page MA 169 L1), Brückner & Ludewig (page MA 170 R5), Denison (page MA 170 R5), Ewing (page MA 169 L6), Gill (page MA 169 L10), Herrmann (page MA 169 L9), Nauss (page MA 170 R4), Smith (page MA 169 L3), and a second article by Allyne (page MA 170 R1). This last states that service results show bad corrosion whenever the soil resistivity is less than 2000 ohm-cms. by the Bureau of Standards test rod. Theory and practise seem to be coming together here.

"Amorphous" metal. Boas & Schmid (page MA 174 R1) show by X-rays that flowed, polished metal is crystalline, not amorphous, while Kersten & Maas (page MA 174 R2) think that electrodeposited black Ni is amorphous, but on heating it becomes crystalline like massive metal. Not much encouragement here for those who talk about "amorphous cement" in ordinary metals.

No. 9 of a Series

The Effect of Two Years of Normal Aging on the Properties of Die Cast Zinc Alloys

Made of Horse Head Special (99.99+%) Zinc

The following tables concern the die cost Zinc Alloys as they are manufactured today. The particular alloys used in these tests are the Zamak* Alloys manufactured by The New Jersey Zinc Co., based on Horse Head Special (99.99+%, Uniform Quality) Zinc.

Die castings are submitted to various aging tests but none have ever been successfully correlated to normal aging. Consequently normal aging figures are the only reliable basis for forecasting service expectancy.

		INDOOR AGING	
		Original[1]	Two Years
ZAMAK 2	4% Al.—3% Cu.—.03% Mg. Balance Horse Head Special Zinc		
	Tensile Strength—Lbs./Sq. In.	47300	48500
	Impact Strength—Ft. Lbs.	15.00	9.25
	Brinell Hardness	83	100
	Per Cent Elongation in 2 Inches	8.4	6.6
	Expansion of 6" Bars in Inches[2]	——	.0006
ZAMAK 3	4% Al.—.04% Mg. Balance Horse Head Special Zinc		
	Tensile Strength—Lbs./Sq. In.	36700	34300
	Impact Strength—Ft. Lbs.	19.50	18.75
	Brinell Hardness	63	68
	Per Cent Elongation in 2 Inches	5.3	6.9
	Expansion of 6" Bars in Inches[2]	——	—.0004
ZAMAK 5	4% Al.—1% Cu.—.03% Mg. Balance Horse Head Special Zinc		
	Tensile Strength—Lbs./Sq. In.	41600	39100
	Impact Strength—Ft. Lbs.	17.75	17.75
	Brinell Hardness	73	76
	Per Cent Elongation in 2 Inches	4.2	4.4
	Expansion of 6" Bars in Inches[2]	——	—.0005
ZAMAK 6	4% Al.—1.25% Cu. Balance Horse Head Special Zinc		
	Tensile Strength—Lbs./Sq. In.	39600	38500
	Impact Strength—Ft. Lbs.	18.50	18.50
	Brinell Hardness	71	78
	Per Cent Elongation in 2 Inches	10.6	9.8
	Expansion of 6" Bars in Inches[2]	——	.0004

[1]Original Properties were determined 6 months after casting date.

[2]Expansions were determined by using the lengths of the impact bars, after 6 months' normal aging, as the original measurements.

*Zamak is a registered trade mark applied to die casting alloys manufactured by The New Jersey Zinc Company from HORSE HEAD SPECIAL (99.99 + %) ZINC. The formulas for these alloys are covered by patents owned by The New Jersey Zinc Company. Licenses to make these alloys with HORSE HEAD SPECIAL (99.99 + %) ZINC under these patents have been granted to a number of manufacturers of alloys and certain commercial die casters who make their own alloys.

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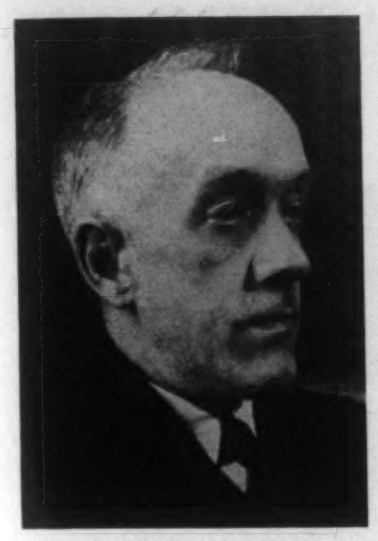
EDITORIAL COMMENT

Maple Sugar versus Sap



THE SYMPOSIUM ON CAST IRON, prepared for and presented at the June meeting of the American Foundrymen's Association and the American Society for Testing Materials adds much to metallurgical literature. Though it is primarily a compilation of information already on record in scattered publications, it is a critical compilation, correlation and interpretation, done by experts, and contains some unpublished information.

In 1931, these societies had a similar symposium on Malleable and in 1932, one on Steel Castings. These publications are available in the bound volumes of Proceedings, and also in separate pamphlet form, really, small-sized books. In our own case, though the library is but a few steps from our office, there are a few summarizing publications that we keep on our own office shelves, close at hand, for continual reference. Among these are the A.S.S.T. Handbook, for sketchy information, the Alloys of Iron Monographs, bound volumes of METALS & ALLOYS for correlated abstracts and abstracts, Edwards, Frary and Jeffries' "The Aluminum Industry," the A.S.T.M.-A.S.M.E. High Temperature Symposium, the Malleable and the Steel Symposia, the A.S.T.M. Report on Present Day Knowledge of Fatigue, and a few others of that type, to which we now add the Cast Iron Symposium.

All these are "boiled-down," authoritative compilations, in which information is easy to find, and with references to more detailed periodical literature. They allow one to refresh his memory, or check up on a disputed point in the quickest possible way. They are immensely more useful than the text book type of book, because they contain more quantitative data, and because they have been so thoroughly checked over by experts that one is not haunted by the fear that some statement is merely that of an individual college professor who may not know whether it is correct or not, but makes it because older text books make it, or who makes it because it is roughly true and good enough for preliminary instruction purposes without taking space to add the qualifications necessary to show its truth or falsity under the conditions in which one may want to use the information.

The labor of preparing these authoritative chunks of maple sugar out of the dilute sap of current literature and information is tremendous, but in the aggregate far less than if each person who needs the data tried to boil it down himself, to say nothing of being a better job and being ready to hand. No greater service can be performed for engineering metallurgy than the publication of such pamphlets. The societies and groups which pursue a continuous program of getting up such symposia in the metallurgical field deserve the applause and support of busy metallurgical engineers.

Ferrous alloys in general will ultimately be covered by the Alloys of Iron series, and these symposia handle the cast ferrous alloys very adequately now, and the Aluminum Company of America has covered the aluminum field. The copper base alloys have been rather neglected from this point of view, and it seems that they should have attention next.—H. W. GILLETT

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Off-the-Trail Metallurgy

METALS & ALLOYS abstractors regularly abstract some 700 metallurgical publications and scientific publications in which metallurgical articles regularly appear. Metallurgy, however, keeps crowding into the interests of, and cropping out in the publications of, groups whose publications are not normally thought of as direct sources of metallurgical information. Some of our readers who have a hobby which brings them into contact with these off-the-trail applications of metallurgy are good enough to send in reprints or to lend us their copies of these publications, so that the metallurgical information can be abstracted.

For example, some metallurgical history recorded in the journal of an Archeological Society, and some technical metallurgy on old coins, from a Numismatic journal, have thus been made available for abstracting, through the courtesy of readers interested in those fields. There are other fields, such as Horology, to pick one at random, in which we need similar help from our readers. —RICHARD RIMBACH

◈ ◈ ◈

Dr. H. A. Smith, of the University of Illinois, has been allotted a National Research Fellowship by the National Research Council for work on transitions in alloys in the Metals Research Laboratory, Carnegie Institute of Technology. The laboratory was previously called the Bureau of Metallurgical Research. It is under the direction of Dr. R. F. Mehl, a member of the Editorial Advisory Board of METALS & ALLOYS.

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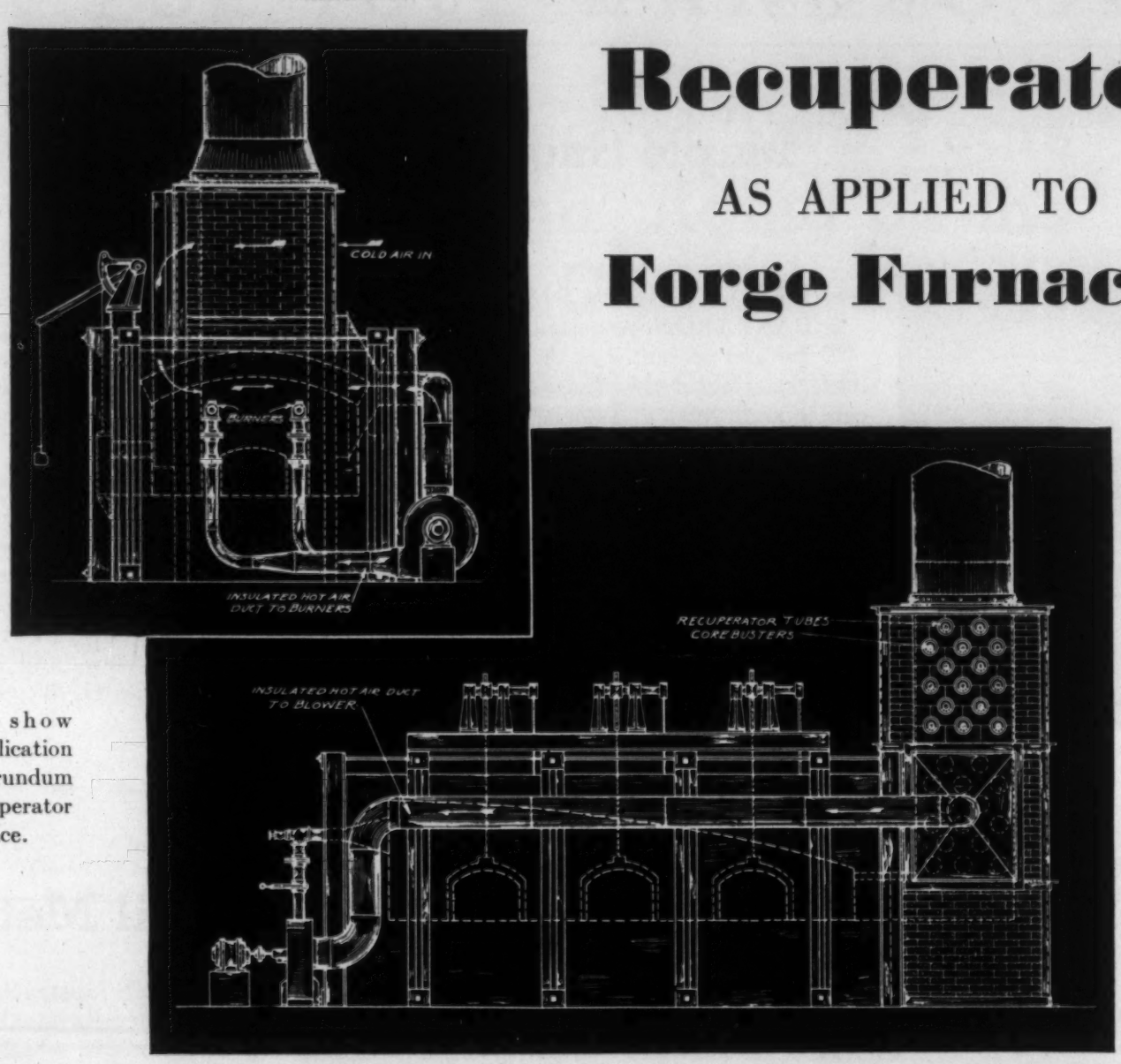

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CUPOLA VERSUS ELECTRIC
Melting of Gray Iron in a SPECIALTY FOUNDRY

By E. A. WISE*

E. A. Wise

DISCUSSIONS of electric versus fuel fired furnaces for ferrous foundry use have been rife of late. In the steel foundry the electric furnace has become practically standard for foundries making the smaller castings while the open hearth remains standard in the big tonnage shops making heavy castings. The temperature required to run light castings can be so much more readily obtained in the electric furnace that there is little question that its selection is justified. The gray iron foundry has not yet gone so completely over to electric melting, since the temperatures required are not so high as for steel, and the cupola—for the temperatures which it can reach—is a much cheaper melting medium than is the open hearth. However, the modern metallurgy of cast iron is trending toward lower carbon, higher melting point irons, and toward superheating to dissolve graphite nuclei and thus allow production of high test iron. With high grade iron as a base, the next step is the addition of alloys for still higher strength products. The cupola admittedly lacks flexibility for such purposes.

One has three alternatives: (1) to drive the cupola hard, and observe the other precautions for obtaining the necessary temperatures and then to exercise very careful control over it to duplicate the conditions heat after heat; (2) to use the cupola for pre-melting only, tapping hot metal into an electric furnace for finishing and superheating; or (3) to rely entirely on the electric furnace, with cold charging.

The choice among these three methods depends on the particular requirements of the foundry. The Baker Perkins Company decided in 1928 to adopt the third alternative. An analysis of the reasons for its choice and a record of its experience with electric melting may be of interest to those confronted with similar problems, especially since the last couple of years have covered a depression period of low production in which the electric furnace is not supposed to show up to best advantage.

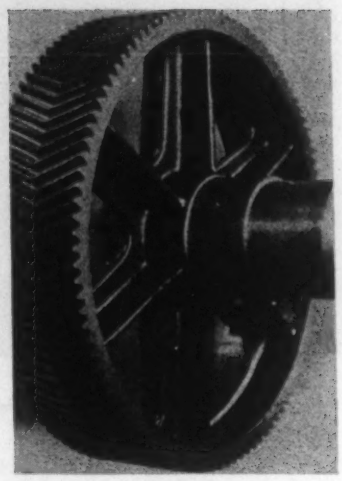

Fig. 1

WHERE much of the output of a gray iron foundry must be made from special iron, and where the requirements vary from day to day and from mold to mold, electric melting, in a rather small unit, proves convenient and flexible, and makes for quality and certainty of operation. These are the times when other specialty foundries should make sure that their melting equipment is definitely fitted to their needs.

The Baker Perkins Company specializes in mixing apparatus for the baking industry, its products being used in the chemical industry as well. Castings for such equipment must be sound, close grained and of definite strength and wear resistance. Many of them are machined on all sides to close tolerance. In dough mixing equipment for example, the rams and knives are ground on all sides and must show no pits that would favor corrosion. We must have a dense, close grained iron that will take a mirror finish. Castings made range in weight from 2 ounces to 2000 pounds, so several grades of iron must be produced for castings of various sections. It was desired to replace some parts formerly made as steel castings and to lighten other parts by using stronger iron and cutting down the cross section. While for some castings a 35,000 lbs./in.^{2} iron will serve, our general requirements range from 45,000 lbs./in.^{2} (in 1″ section) up to 65,000 lbs./in.^{2} for special gears such as the 44 in. diameter, 8 in. face heavy duty gear of Ni Mo iron shown in Fig. 1, which weighs 1450 pounds, has a tensile strength of 67,500 lbs./in.^{2}

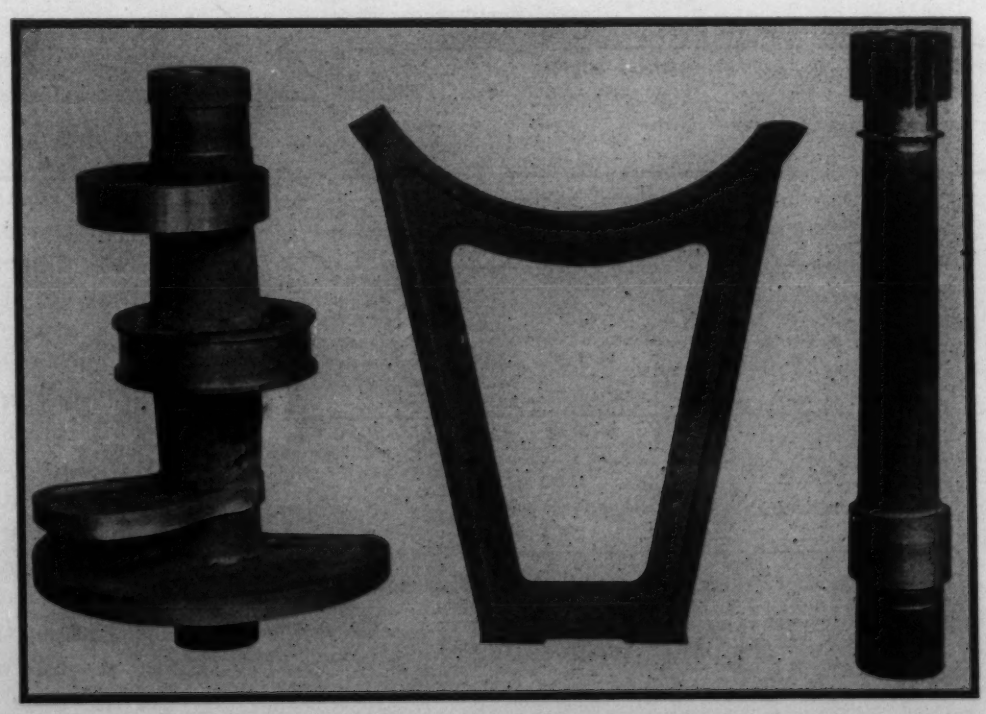

Fig. 2—Engineering applications of high strength electric gray iron castings.

*Foundry Superintendent, Baker Perkins Co., Inc., Saginaw, Michigan.

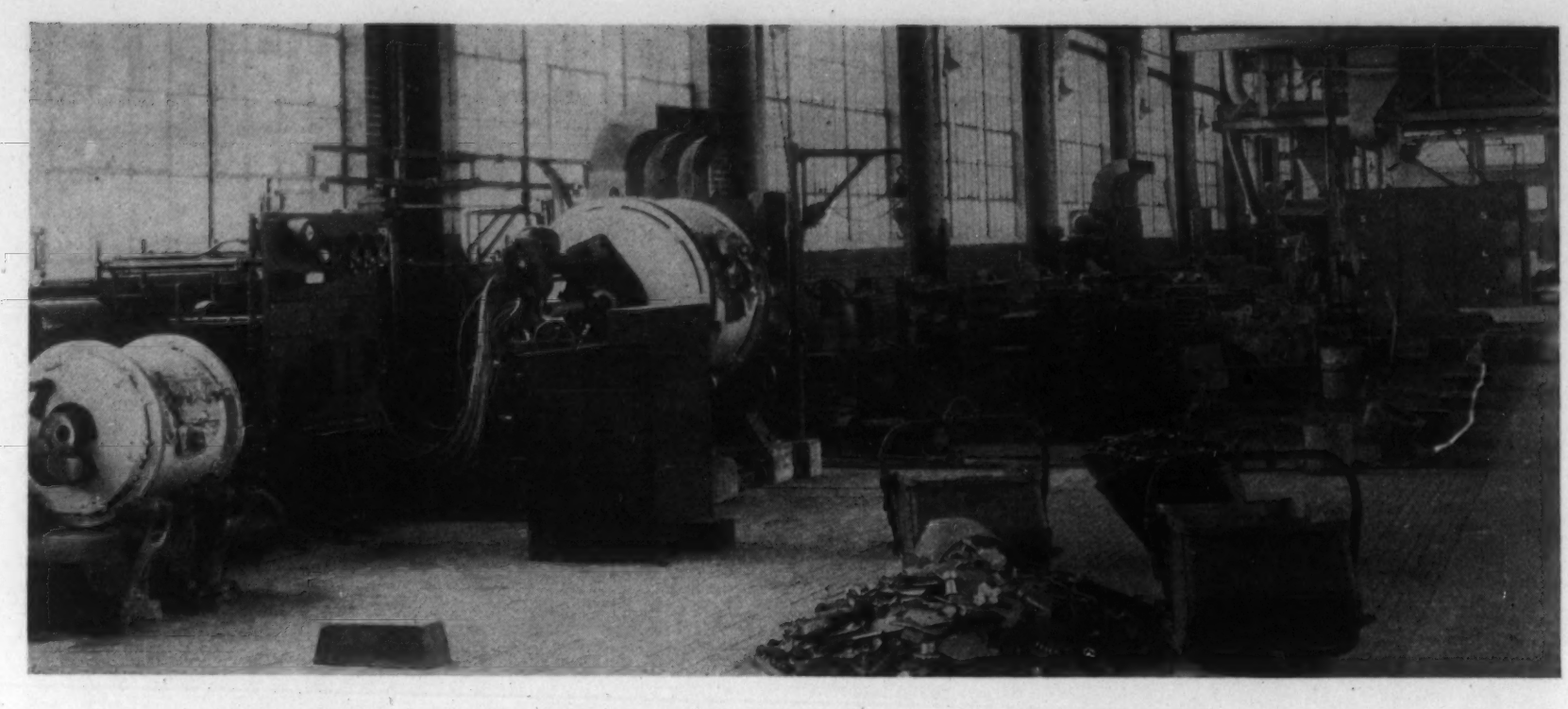

Fig. 3—Jobbing foundry floor alongside main bay. Smaller electric furnace is used for melting bronze and aluminum.

and a Brinell hardness of 235. Another feature entering prominently into our problem was the fact that it was desired to utilize both our machine shop borings and a considerable amount of steel punchings produced in our fabricating department.

Fig. 2 illustrates three types of castings now made of electric furnace irons for specific requirements. The casting on the left is a four-way cam made in one piece of high-strength electric iron, requiring exceptional wear-resistance properties, because of the extreme usage of these cams in metal-to-metal working surfaces as required in the modern dough-handling equipment used in the baking industry. The part on the right shows an exceptional adaptation of high strength electric iron in casting a bearing, sprocket gear and pinion integral with the shaft for a unit assembly requiring a uniform material having good machine properties and a minimum tensile strength of 50,000 lbs./in.^{2} The casting in the center illustrates the replacement of a steel casting by high strength electric iron.

In making castings of these types, the compositions used range from 2.50 to 3.00% total C and 1.75 to 2.25% Si, depending upon the sections. This is illustrated in the accompanying table showing the compositions used.

We doubted our ability to secure the required physical properties from the cupola, even at the cost of excessive coke consumption. Moreover we wanted the extreme of flexibility so that a few light castings could be poured and the rest of the melt put into heavy castings or vice versa, for both types are often waiting on our molding floor at the same time. Again, we did not believe that "stovepipe" charging or briquetting would allow us to utilize our borings and our small steel scrap in the cupola in a satisfactory manner. In September 1929, we began using a Detroit rocking electric furnace of 1000 pounds rated capacity in which we regularly charge 1500 pounds, though the heats may vary between 200 and 2500 pounds. The furnace equipment and the main bay of the foundry are shown in Figs. 3 and 4.

In order to use up our stock of borings we originally charged all borings, plus steel scrap when necessary, in the electric furnace, sending the gates back to the cupola. We expected to use the cupola for everything for which it would serve and make special compositions in the electric. As time went on, our cost figures showed, however, that, considering the lower cost of the charges, the electric iron was cheaper in the ladle than the cupola iron, even though we ran the electric furnace only 8 to 12 hours per day. Moreover, the engineering department, having the stronger electric irons available, demanded the higher strength product, and we soon found ourselves on an all-electric basis, using the cupola only for those few castings requiring more than 2,500 pounds of metal.

At the time regular cupola operation was discontinued in 1930, the compara-

Table of Standard Mixtures—Cupola and Electric Irons.

Casting Section	Iron Grade No.	Total Carbon	ANALYSIS Si	Mn	S	P	Ni	Mo	Cu	Cr	Tensile Strength lbs./in.^{2} Cupola Iron	Electric Furnace Iron	Castings Made
* 1" or more	1	3.25 to 2.95	1.00 to 1.90	.6 to 1.00	.05 to .08	.18 to .25					36,000		General Machine Parts.
	1 A	3.00 to 2.80	1.00 to 1.90	.6 to 1.00	.05 to .08	.18 to .25						45,000 to 50,000	Castings requiring close grain structure.
	1 B	3.00 to 2.50	1.00 to 1.90	.6 to 1.00	.05 to .08	.10 to .20	1.00	.5				60,000 to 70,000	High strength, long-wearing gears and pinions.
½" to 1"	2	3.40 to 3.25	2.00 to 2.40	.6 to 1.00	.05 to .08	.35 to .40					28,000		Gears, sprockets, etc., where strength, machineability and long wearing qualities are desired.
	2 A	3.10 to 2.80	2.00 to 2.25	.8 to 1.00	.05 to .08	.20 to .30						35,000 to 45,000	
Under ½"	3	3.40 to 3.75	2.25 to 2.60	.8	.05 to .08	.40 to .60					20,000		Frames, brackets and miscellaneous parts where good machineability is a primary requirement.
	3 A	3.50 to 3.00	2.25 to 2.60	.8	.05 to .08	.35 to .40						30,000 to 35,000	
	Special Alloy	2.75 to 3.10	1.25 to 2.00	1.00 to 1.50	.04 to .12	.04 to .30	12% to 15%		5% to 7%	1.50 to 4.00		25,000	Ni-Resist for corrosion resistant parts.
	Special Alloy	3.00 to 3.10	1.40 to 1.45	1.00 to 1.10	.08 max.	.20 max.	20%			2.0%			Copper-free Ni-Resist. For acid resistance.

*Castings range from 1" to 4" in section.
The carbon-silicon ratio is arranged according to the section.

Fig. 4—Main bay of the Baker, Perkins Company Foundry at Saginaw, Michigan.

tive costs of electric furnace and cupola iron at the spout showed a saving of $2.00 per ton in favor of electric iron, the actual cost figures being $0.0115 per pound of cupola iron and $0.0105 per pound of electric iron. Due to the fact that our requirements for high quality metal in our castings necessarily involved the use, in our cupola, of a high percentage of pig iron as well as of carefully selected scrap, the cost of our cupola metal at the spout was comparatively high.

The facility for control in our electric furnace, together with its capability of using all scrap and borings mixtures, effects a substantial saving in favor of the electric furnace upon our class of production work. These costs naturally vary with the rate of production and market conditions, but the following may be cited as typical recent electric furnace costs, which are obtained under the present very unfavorable production schedules. These electric furnace costs such as electrodes, refractories, labor and especially furnace power cost will, obviously, be materially lowered upon any resumption of business conditions which will improve our load factor and general operating practice.

	Per ton
Power: 650 kilowatt hours @ 2c	$13.00
Electrodes: 8½ lbs. @ 17½c per lb	1.49
Refractory maintenance, materials and labor	1.00
Labor: 76c per hr., 6500 lbs. production in 9 hours	1.94
Maintenance, repairs and supplies	.10
Total conversion cost	$17.53
Material:	
50% borings @ $5.00	$2.50
10% steel scrap @ $7.50	.75
25% returns @ $6.33	1.59
15% scrap @ $10.00	1.50
Total material	$6.34 6.34
Total cost per ton of metal at the spout	$23.87

As we veered away from the use of the cupola and used up our accumulation of borings, the charges of course were no longer all borings, though we purchase some outside borings. The present charges are generally 50% cast iron borings, 40% cast iron gates and scrap, and about 10% steel scrap—the last varying with the composition desired. We have never charged any pig iron into the electric furnace. This, plus the higher properties of the electric iron and the greater flexibility of its operation, make electric practice fit our particular needs very well. With higher production we might use the cupola to deliver hot metal to the electric for superheating and adjustment of composition, but we consider that the operation and synchronizing of two different melting media presents too much of a complication to be economical under our present conditions.

With electric furnace practice, we have adopted a plain iron of

2.95% total C, 1.25% Si for heavy castings, one of
3.00% total C, 2.00% Si for medium, and one of
3.40% total C, 2.25% Si for light castings,

or say, for 1″ section or heavier, 2.95—3.25% total C, 1.00—1.90% Si, 0.60—1.00% Mn, S 0.05—0.08%, P under 0.20%. In the cupola this gave us 36,000 lbs./in.^{2}, but we wanted 45,000. We found that we could get the latter figure from that composition in the rocking electric furnace, and by dropping the C slightly, superheating to 2900° F. and rocking to destroy graphite nuclei, we could raise the strength to 50,000 lbs./in.^{2} without the use of alloys.

For still stronger castings, we drop the C and Si slightly and add 1% Ni and 0.50% Mo. This gives us 60,000 lbs./in.^{2} and by superheating to 2925° F. and rocking, we get 65,000 or above. In some cases, for special purposes, we use all steel scrap plus coke and ferrosilicon, i.e., a synthetic iron, either by itself or as a base for alloying, when specially strong iron is required.

The initial furnace charge is calculated on the low Si side if the bulk is to be poured into heavy castings, if into light castings, on the high Si side. A step-bar is poured and the fracture and chill examined, and any slight adjustment of the charge is made for the main pour. The balance in the furnace is then adjusted, with crushed coke and ferrosilicon in the case of lighter castings, or with steel additions for heavy ones. Since the temperature is kept high and the furnace is rocked, the additions are rapidly taken up. Alloy additions are also readily absorbed giving accurate alloy control and low loss.

In spite of the high operating temperature, our first lining lasted 20 months and gave 1500 heats, while the present lining has already been in service two years, and has so far given over 1800 heats.

The refractory used is an aluminum silicate material of approximately 65% alumina content, the lining being of monolithic construction. The entire refractory is of approximately 4″ thickness on both circle and end walls and was installed by ramming into place with an

air rammer. It has been maintained in service, during the past two years, by patching over week-ends. The only maintenance required during the week is the occasional patching around the door section. Each week-end the lining is put into proper operating condition for the following week's run by chipping out any loose or accumulated material and doing any general patching required. Care is taken to see that the patches are keyed into place, i.e., that the lining is slightly undercut before applying a new patch. In this manner we are able to keep the lining in constantly satisfactory operating condition for an indefinite period of time. Total refractory maintenance costs have averaged $1.00 per ton of metal.

The flexibility necessary in our practice would be difficult to attain by other methods than electric melting. Instead of pouring a mold out of whatever metal at whatever temperature the cupola will produce, we are able to do a "tailor-made" job, putting into each mold just the metal it needs. While many other factors in foundry practice enter in, we ascribe our very low machine shop scrap largely to this fitting of the metal to the job. We now feel virtually certain that, once a casting leaves the foundry, it will finish perfectly in the machine shop, and that it will stand up to its job in actual service.

We recognize that the cupola is not obsolete for the conditions existing in many foundries, though it is practically obsolete for us, and we know that high test iron and alloy iron can be successfully produced from the cupola under expert control. But where a large proportion of the output must be made from special iron, and where the requirements vary from day to day and from mold to mold, as they do with us, the flexibility of electric melting, in a rather small unit, offers so much for convenience, quality and certainty of operation that we believe these are just the times when other specialty foundries should make sure that their melting equipment is definitely fitted to their needs, and in foundries like ours, we feel that electric melting is likely to be the best answer. Under other conditions the opposite may be true, but at any rate, we have worked out a method of operation that is a marked improvement over our older methods for our particular conditions.

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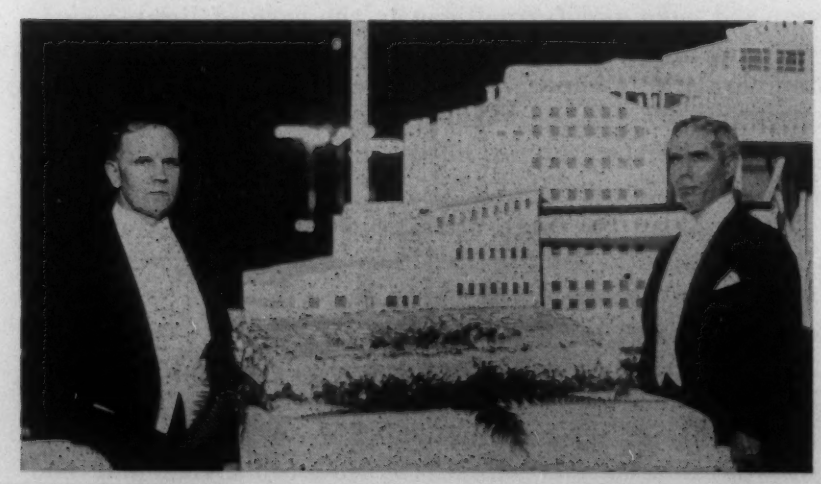
50 Years of Canada's Nickel Industry

Dr. John A. Allan, president of Canadian Institute of Mining & Metallurgy, and Robert C. Stanley, president, International Nickel Co. of Canada, inspect nickel's golden anniversary birthday cake at annual banquet of the Institute in Toronto. In the background is a 12-foot model, built of sugar, of the Nickel Company's mill and smelter at Copper Cliff, Ont.



Dr. Allen Mr. Stanley

READERS' COMMENT

Editor, METALS & ALLOYS:

We have read with great interest the article by C. S. Barrett on the "Nature of the Solid Solution of Aluminium in Silver" published in your May issue. In a conversation with Dr. Barrett, held some months ago, it was agreed that this subject was of such importance that it would be desirable to have several independent investigations on the subject. Accordingly we also investigated this system.

Although our investigation is not quite completed, we fully substantiate Dr. Barrett's conclusion that the solid solutions at the silver end of this series of alloys are of the simple substitution type. This represents additional evidence that the complex type of solid solution proposed by Phelps and Davey is incorrect. In comparing the results of three investigations, it was found that, with the exception of Phelps and Davey's measurements on the 4.34 and 5.04 weight percent aluminium alloys, the density measurements agree surprisingly well; the two exceptions noted are too low by approximately 0.1 density unit.

Our measurements on the lattice constants of these alloys are quantitatively somewhat different from those of Dr. Barrett by amounts which seem to be beyond the limits of experimental error of the two methods used; this point is being investigated more closely. The most important results, however, are (1) that the slope of the lattice parameter vs. atomic percent Al curve found in this laboratory is practically identical with Dr. Barrett's and widely different from that of Phelps and Davey, and (2) that the number of atoms per unit cell from our results is 4 within the limits of error in the density measurement.

We intend to complete the investigation of these alloys and determine the solubility limit at the end of the system. If the results appear to be of sufficient interest, we shall submit a detailed report.

School of Mines
Columbia University
New York, N. Y.
May 22, 1933.

E. R. JETTE
FRANK FOOTE

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At the annual meeting of the American Welding Society, held at the Hotel Governor Clinton in New York on April 27 and 28, the Samuel Wylie Miller Medal was awarded to **H. H. Moss** of New York "for his achievement in the application of fusion welding and oxy-acetylene flame cutting." The Samuel Wylie Miller Medal is an annual award of the American Welding Society and is presented for meritorious contributions to the science and art of welding. This medal was established in 1927 by the late Samuel Wylie Miller, himself an outstanding figure in the development of welding since its inception.

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Testing Equipment at A Century of Progress

The recent developments in both Tinius Olsen Universal Testing Equipment and Balancing Equipment will be exhitited and demonstrated at the coming "Century of Progress" in Chicago from June 1st to Nov. 1st.

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New Rolling Mills Ordered

The American Sheet & Tin Plate Company, Jones & Laughlin Steel Corporation and Republic Iron & Steel Company have placed orders with United Engineering & Foundry Company at Pittsburgh for major equipment to produce light gage material in strip form.

The American Sheet & Tin Plate Company mill is expected to be installed in the Chicago district, the Jones & Laughlin mill in the Pittsburgh district and the Republic mill in the Youngstown district.

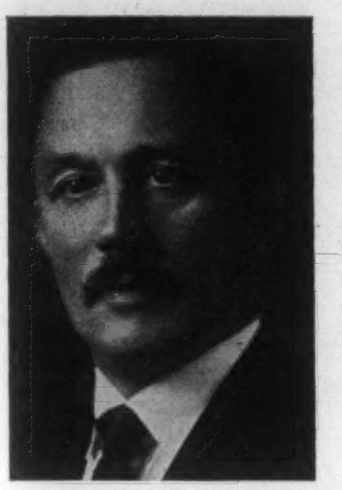
At present, United Engineering at its Youngstown plant is completing for American Sheet & Tin Plate Company what is believed to be the largest single stand cold mill built up to this time. This is the 4-high mill, driven work roll type.

SURFACE TENSION of MOLTEN METALS

A CORRELATED ABSTRACT

By A. I. KRYNITSKY

PECULIAR RESULTS in the "runability" or free-flowing properties of cast metals indicate the need for a better fundamental knowledge of surface tension of molten metals and alloys. Similarly, interfacial tension data, were they available, would throw much light on soldering problems. The surface tension of copper in hydrogen would be of great interest in relation to "copper brazing." Methods of determination of surface tension and the scanty data available are brought together in this correlated abstract.



CONCEPTION OF SURFACE TENSION

IT is well known that within the *limiting distance* S the molecules attract their neighbors and are attracted by them; and that a molecule situated in the body of liquid will be in equilibrium by virtue of the equal attractions on all sides, i. e. the molecular attractions acting upon an element of the liquid are, on the whole, completely balanced; the element is pulled as strongly in one direction as in another. Every particle of a liquid is attracted by cohesional forces and by gravitational forces.

The mutual gravitational forces, however, are very small in comparison with the cohesional forces, and therefore may be neglected. The cohesional forces are directly proportional to the masses of attracting particles and to some function of the above-mentioned distance which is called the radius of cohesional activity. Experiments by Quincke and others have shown that these postulated forces cannot be sensible over distances exceeding 5×10^{-5} mm.

As the surface is approached the balance of the molecular attractions acting upon an element of the liquid is destroyed. Near the surface the element is pulled more strongly toward the liquid, or else the reverse is true. This lack of balance in the molecular forces is what gives rise to the property that we call "surface tension."

The lack of balance, and consequently the surface tension, depends upon the properties of both of the media of which the surface is the common boundary.[1] Surface tension is not a property of one medium, but is the joint property of two media. When one speaks of the surface tension of a particular liquid, what is meant, or at least what should be meant, is the surface tension of the liquid in contact with its own pure vapor at the same temperature. Actually, the surface tension of the interface separating a liquid from a gas or vapor depends but little upon the nature of the latter, provided that it does not react chemically with the liquid, and that certain exceptional conditions are excluded. All the equations employed in the reduction of surface tension measurements are based upon the assumption that the transition layer in which the forces are unbalanced is of negligible thickness. Should conditions, as Dorsey[1] says, ever arise in which this assumption is not justified, then either we must completely reconsider the equations, taking into account the variation in the forces as we pass through the surface layer, or we must change the scale of our operations in such a manner that the thickness of the transition layer becomes negligible in comparison with the smallest length which we can measure upon the revised scale. Consider now a particle nearer the surface of a liquid than the above-mentioned radius S of cohesional activity. In this case the horizontal attractions will be equal in all directions, but the vertical attractions are unequal; the resultant being an unbalanced component towards the interior of the liquid. To illustrate this let AB^2 in Fig. 1 represent the surface of liquid and A_1B_1 an imaginary surface parallel to AB and at distance below it equal to the radius of cohesional activity.

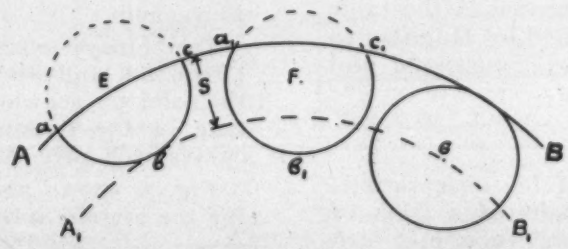


Fig. 1. Surface of liquid showing spheres of cohesional activity (after Libman).

Consider particles of liquid at E, F and G and draw about them spheres of radius S. Of the spheres drawn about particle E only hemisphere exists in the liquid and cohesional forces acting upon this particle come only from the particles of this hemisphere. From symmetrical arrangement of these particles it follows that the resultant force is in the direction Eb which is normal to surface at E. Cohesional forces acting upon particle F come from the particles of the portion $a_1\ b_1\ c_1$ of the sphere. The resultant force in this case is again in direction Fb_1 and is less than at E because liquid above F exerts upward force. The particle G is completely surrounded by liquid and the resultant force upon it is zero.

Thus, every particle in the extremely thin surface layer of thickness S of a liquid is urged inward by a force normal to the surface and the mass of liquid behaves as if surrounded by an elastic bag under stress, tending to contract and compress the liquid into as small a volume as possible. This is due to "surface tension."

The surface of a liquid is therefore a seat of potential energy, since in order to force a molecule from the interior of the liquid out into the surface film, work must be done in moving the molecule through the distance against the force tending to draw it back into the interior. An increase in area of the surface film, therefore, means an increase in its potential energy, and since potential energy always tends to become a minimum, it follows that if a liquid mass be freed from the action of other forces, it will assume such a form that its surface will be a minimum, and its volume a maximum; that is, it will assume the form of a sphere.

SOME OF THE METHODS USED IN MEASURING SURFACE TENSION AND RESULTS OBTAINED

Different methods have been proposed for measuring the surface tension of liquids, but most of them are not suited for precise work with metals at high temperatures.

Cantor's Method

The method originated by Cantor[3] consists in determining the pressure necessary to force a bubble of inert gas from the end of a sharp-edged capillary immersed at the surface of liquid.

The formula of surface tension derived by Cantor and corrected by Feustel[4] is as follows:

$$T = \frac{pr}{2}\left(1 - 2/3\,\frac{dr}{p} - \frac{d^2r^2}{p^2}\right) \text{ where}$$

Table I. Surface Tension of Some Metals in Dynes/cm. at Various Temperatures

°C.	Hg	°C.	Bi	°C.	Sb	°C.	Pb	C°.	Sn	°C.	Cu	°C.	82%Cu + 18%Sn	°C.	25%Cu + 75%Sn
19	473	583	354	750	368	750	423	878	508	1131	1103	962	911	700	543
43	464	587	353	800	367	800	418	900	506	1150	1115	1000	922	800	542
86	454	590	356	900	361	900	407	1000	497	1200	1154	1050	935	900	540
106	450	770	343	1000	355	1000	401	1050	492	1215	1166	1100	943	1000	538
159	441	779	344	1100	348	1036	397					1116	945	1080	536
201	429														

T is the surface tension
r is the radius of capillary
p is the pressure
d is the density of the liquid

This method was extensively applied by Jaeger[5] to organic liquids and molten salts and was used also by Sauerwald and Drath[6] in their investigation on the surface tension of number of molten metals and alloys. Some of their results are presented in Table I and in Figs. 2 and 3.

Table No. I and Fig. 2A indicate that there was a decrease of the surface tension of mercury, bismuth, antimony, lead and tin with an increase in temperature, whereas the opposite phenomenon was observed with copper, i.e. the surface tension of copper increases with an increase in temperature.

Correspondingly, the surface tension of copper-tin alloys containing a greater amount of copper than tin increased with rise of temperature, whereas the surface tension of alloys containing more tin than copper decreased with an increase of temperature.

Examination of Fig. 3A shows that in bismuth-tin alloys an increase in surface tension was inversely proportional to rise in temperature. Similar observations were made by these authors on the surface tension of bismuth-lead alloys.

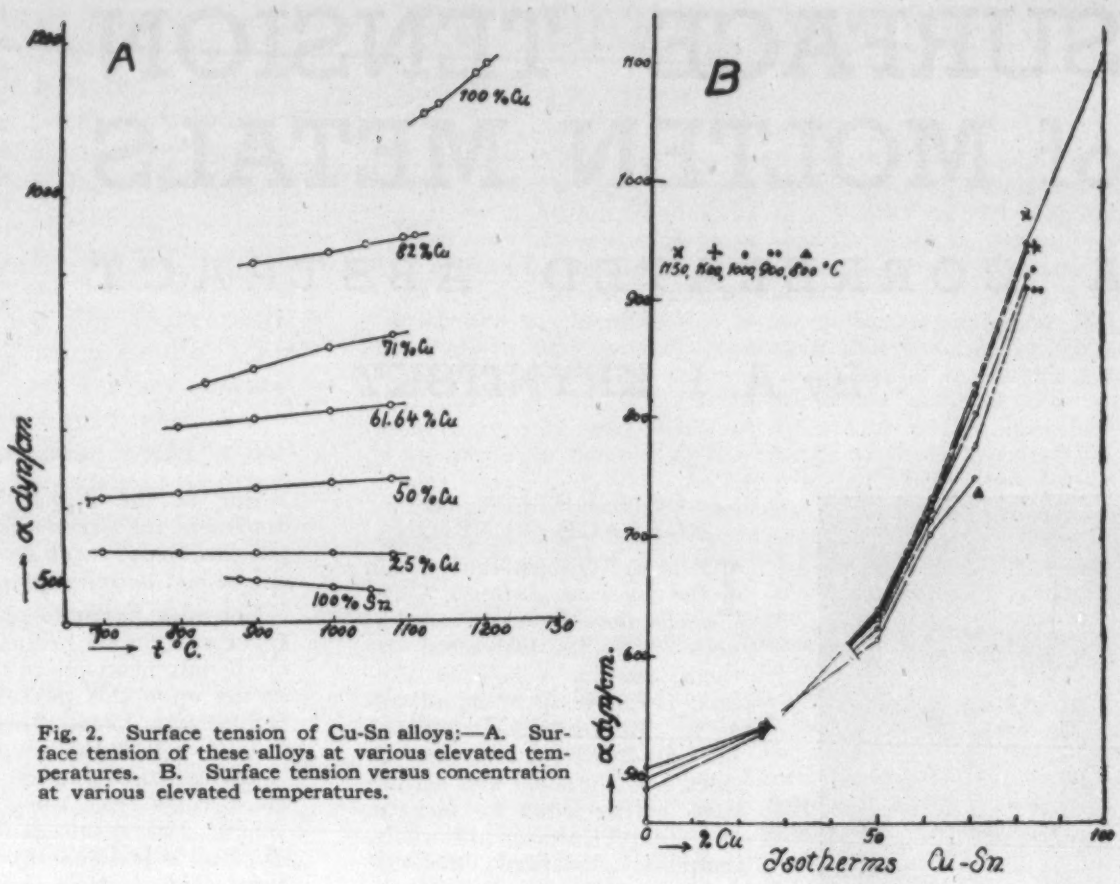


Fig. 2. Surface tension of Cu-Sn alloys:—A. Surface tension of these alloys at various elevated temperatures. B. Surface tension versus concentration at various elevated temperatures.

Isotherms shown in Figs. 2B and 3B indicate that in the bismuth-tin and copper-tin alloys the addition of an element possessing a greater surface tension caused an increase in the surface tension of those alloys.

The isotherms obtained with copper-antimony alloys were very similar to those of copper-tin alloys.

Hogness,[7] who determined the surface tensions of liquid mercury, cadmium, zinc, lead, tin and bismuth, reversed Cantor's method so as to measure the pressure necessary to force a tiny drop of liquid investigated from the tip of a quartz capillary directed upwards. The values obtained were plotted and smooth curves were drawn through the points.

The values of surface tension calculated at a series of temperatures from these smooth curves are presented in the table No. 2. The values of surface tension determined by Hogness to a certain extent supplement those given by Sauerwald and Drath (see Table I).

Drop Weight Method

In 1864 Tate[1] announced as the result of his observations that "other things being the same, the weight of a drop of liquid is proportional to the diameter of the tube in which it is formed."

Although this method is not free from theoretical uncertainties, Matuyama[8] obtained interesting results by it.

He measured the weight of a drop falling from the mouth of capillary tube of known diameter and calculated the surface tension according to Lohnstein's formula—

$$W = 2 \pi r \alpha f$$

where W is weight of the hanging drop
r is radius of the base of hanging drop
α is surface tension required
f is function of r/α

Within the range of temperatures used, the surface tension-temperature curves of pure metals studied by Matuyama (Fig. 4) were linear and of practically the same slope.*

The surface tension of tin determined in air was higher than in vacuum.

Two binary systems, cadmium-antimony and zinc-antimony (Figs. 5A and 5B) each have an intermetallic compound in the solid phase, which does not decompose up to the temperature of the liquidus, and the surface tension-concentration curves each have a break at the concentration of the compound.

Fig. 6 shows also the surface tension-concentration curve for the system antimony-lead, which has no intermetallic com-

*All determinations except one were made in vacuum.

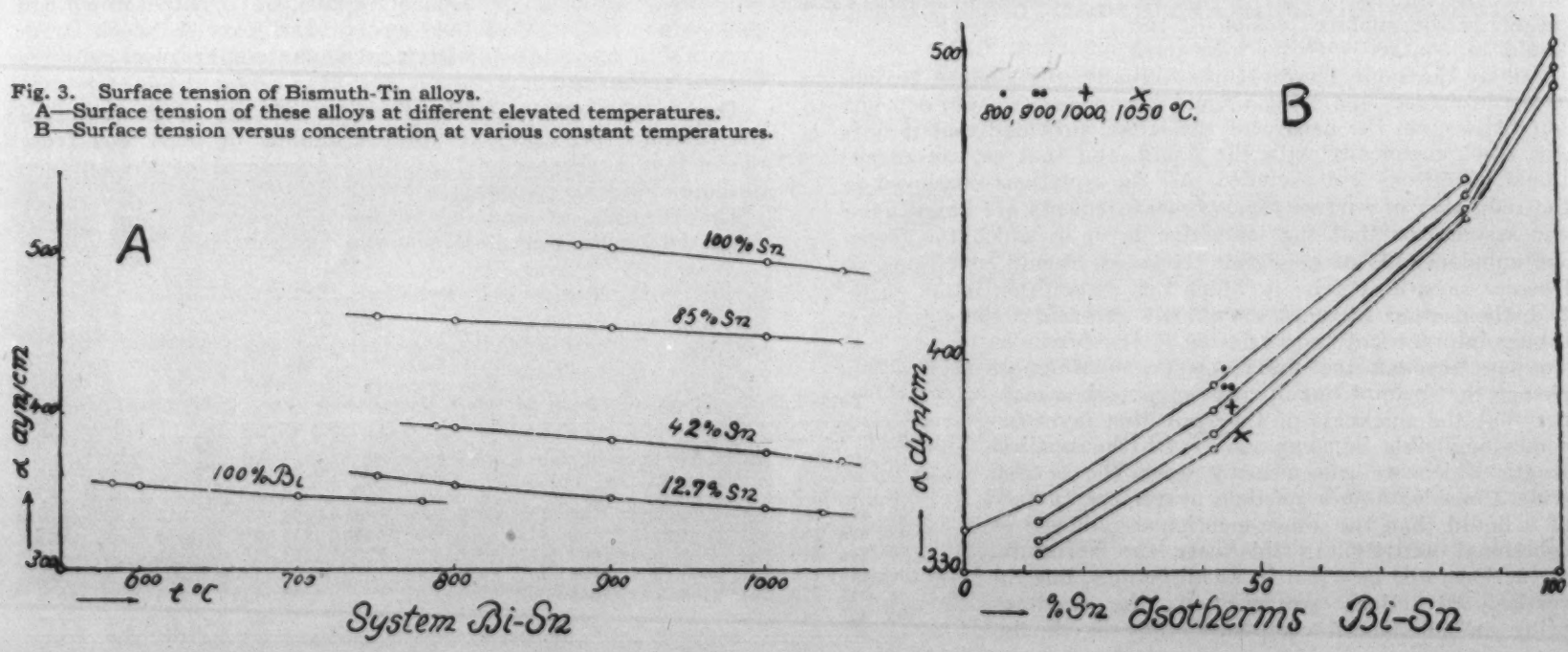


Fig. 3. Surface tension of Bismuth-Tin alloys.
A—Surface tension of these alloys at different elevated temperatures.
B—Surface tension versus concentration at various constant temperatures.

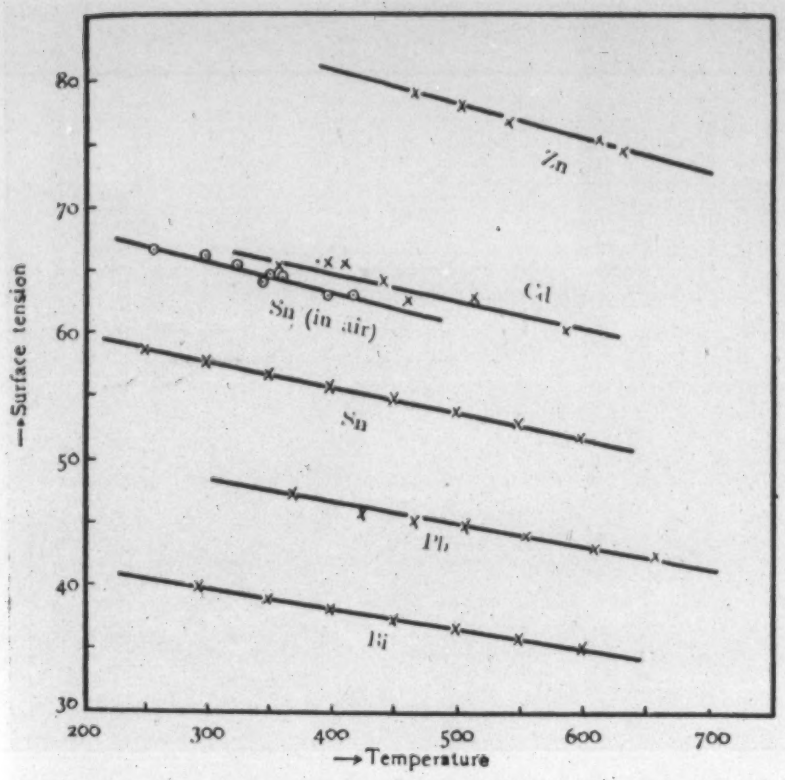


Fig. 4. Surface tension-temperature relation in some pure metals obtained with a drop weight method.

Table II. Surface Tension of Some Metals in Dynes/cm. at Different Temperatures

° C.	Hg	Bi	Pb	Sn	Cd	Zn
0	465					
20	463					
50	460					
100	453					
150	445					
200	435					
250	422					
300	408	376		526		
350	393	373	442	522	628	
400		370	438	518	625	
450		367	438	514	622	755
500		363	431	510	618	751

Now if the material forming the plane is the same as that composing the tube, and the liquid is the same in both cases then $Q_1 = Q_2$ and $T_1 = T_2$ and we will have:

$$h_1 = F_1\ (TQ)$$
$$h_2 = F_2\ (TQ)$$

We have now two unknowns T and Q and two equations. Therefore T and Q may be determined if h_1 and h_2 are known.

It may be proved[2] that

$$\frac{2T}{gd} = a^2 \text{ capillary constant and}$$

$$a^2 = \tfrac{1}{2}\left(\frac{h_2{}^2\, r^2}{h_1{}^2} + h_1{}^2\right)$$

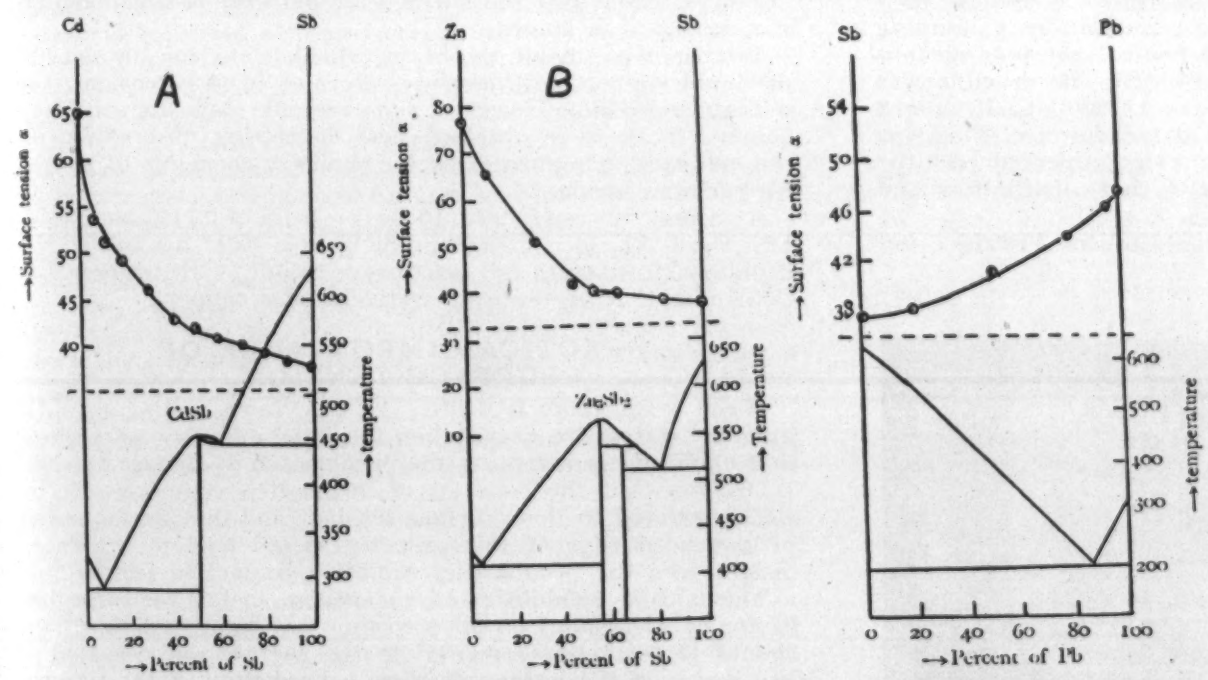


Fig. 5. Surface tension-concentration diagrams obtained with a drop-weight method in: (A) Cd-Sb alloys; (B) Zn-Sb alloys.

Fig. 6. Surface tension-concentration diagram obtained by a drop weight method in Sb-Pb alloys.

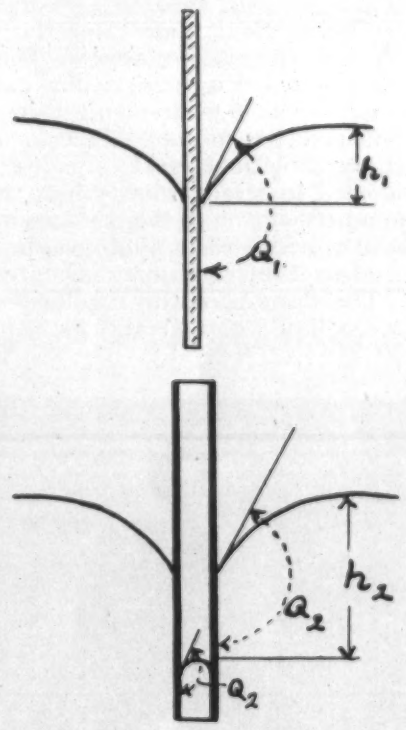


Fig. 7. Plane and Capillary depressions.

pound. This curve rises continuously from one component to the other without showing any break.

Hence, Matuyama concluded that an intermetallic compound existing in a solid phase does not decompose during melting and exists as such in the liquid phase.

Libman's Determination of the Capillary Constant of Copper.

If a vertical plane is dipped into the level surface of a fluid which does not wet the plane, the fluid is depressed, that is, the line of contact of the fluid with the plane will be lower than the level of the fluid.

The magnitude h_1 (Fig. 7) of the depression will depend upon the properties of the liquid and the solid forming the plane, that is, upon the surface tension T_1 and the angle of contact Q_1 and

$$h_1 = F_1\ (T_1 Q_1)$$

If a capillary tube be placed with its lower end beneath the level surface of a liquid which does not wet the tube, the liquid will stand within the tube at a lower level than the surface without. The depression is again the function of Q_2 and T_2 and

$$h_2 = F_2\ (T_2\, Q_2)$$

where T is the surface tension
d is the density of a given liquid
g is the value of acceleration due to gravity
r is the radius of capillary

These equations are perfectly general and hold for all liquids subject only to gravity.

These formulas were used by Libman in his work in determination of capillary constant of copper.

The method used by Libman was as follows: a special covered crucible (Fig. 8) was made of alundum.

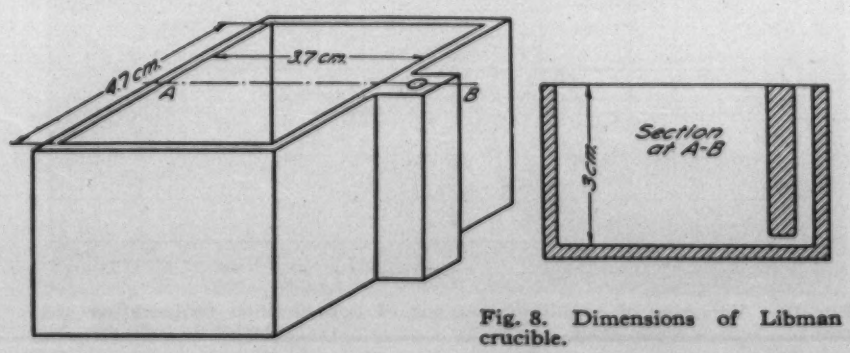


Fig. 8. Dimensions of Libman crucible.

Ajax Induction Furnaces at the Duriron Company, Inc., Dayton, Ohio

The vertical plane and the capillary tube were composed here of the same material. The electric furnace used to melt the metal had a housing that could be evacuated by a pumping system. The measurements were made from X-ray photographs taken at ten minute intervals. (See Fig. 9) The crucible was charged with a block of pure copper. At 900° C. hydrogen allowed to stream slowly into the evacuated furnace. This was pumped out and the treatment was twice repeated. As the temperature rose photographs showed that distillation and condensation of copper occurred.

The data give the capillary constants of the interface between liquid copper and its vapor.

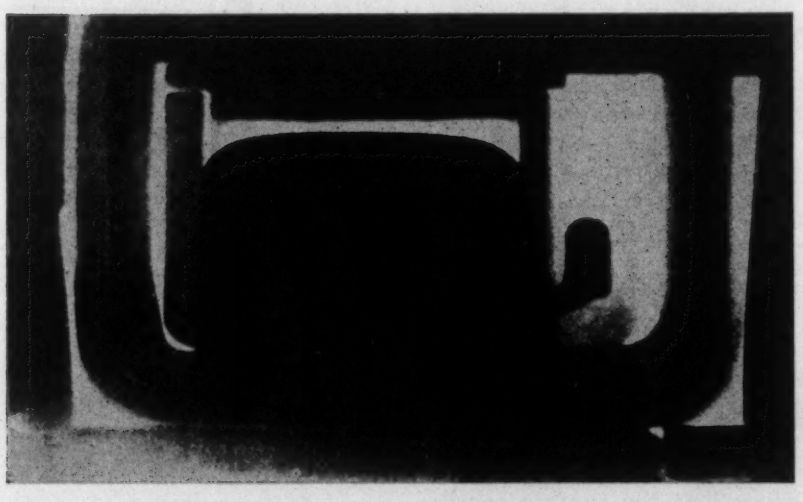


Fig. 9. Reproduction of typical X-ray photograph from the negative of which measurements were taken.

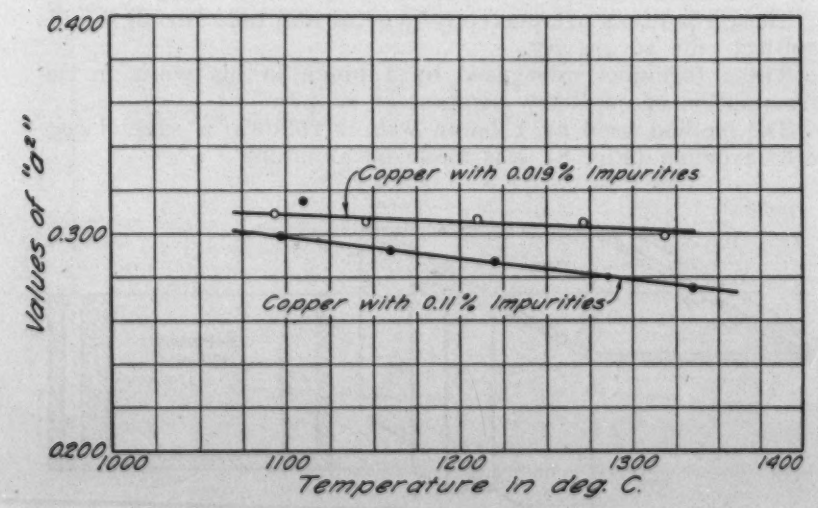


Fig. 10. Variation of capillary constant of copper with temperature (in cm^2.)

Having determined $h_1 h_2$ and r we obtain the capillary constant a^2. From this the surface tension may be calculated if the density d is known.

Libman was unable to obtain reliable data for the density of liquid copper and therefore values of surface tension were not given by him. However, very accurate data for capillary constants, a^2, were obtained and interesting observation on the influence of impurities on the capillary constants of molten copper were made.

As it may be seen in Fig. 10 the presence of 0.11% impurities ($Fe_2O_3 + Al_2O_3 = 0.07\%$ and $SiO_2 = 0.04\%$)* has caused the capillary constant to fall much more rapidly with temperature than does that of the comparatively pure copper.

PRACTICAL IMPORTANCE OF SURFACE TENSION

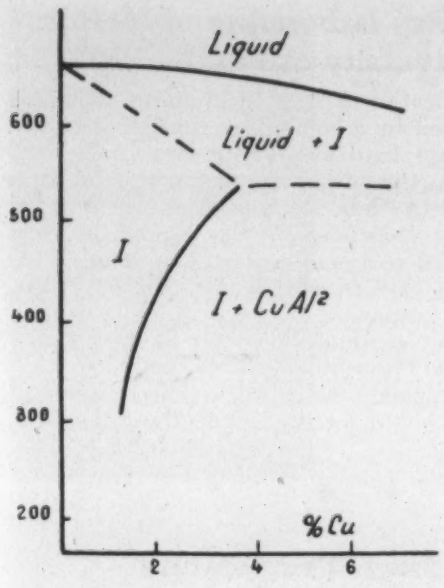
When a substance is molten the only forces acting upon it, Libman[2] states, are gravity and the intermolecular attractions that manifest themselves in the phenomenon of surface tension. It follows that the behavior of the molten materials will be closely related to their surface tensions and that an extension of our knowledge of this property should lead to a greater insight into the peculiarities exhibited by molten metals.

The mutual solubilities of the molten metals, and the behavior of such solutions upon cooling and before solidification, should likewise be so related to the surface tensions that a knowledge of the latter will allow a prediction of the former. In casting operations where sharp outline is necessary the surface tension of the molten metal is the governing factor. Metals with high surface tension will not flow into sharp corners or crevices and if the latter be sufficiently fine an enormous pressure would be required to force the liquid into them. The previously-held idea that the metal must expand, or at least not shrink, on cooling, in order to get sharp castings, is giving way before the suspicion that those materials whose addition increases detail in casting are just those that cause a lowering in the surface tension of the melt.[2]

It should be pointed out, however, that in their recent paper on fluidity of pure metals (Sn, Cd, Pb, Zn, Sb, and Al), Portevin and Bastien,[9] considering experimental data and mathematical analysis of the phenomenon of fluidity came to the conclusion that the forces of surface tension do not appear to play an important part in fluidity.

On the other hand in reviewing some other works one cannot escape the suspicion that the running quality of metal is closely related to its surface tension. It has already been shown (see Table I and Fig. 2B) that in Cu-Sn alloys the surface tension of these alloys showed a decrease with an increase in the Sn content. Therefore and provided that surface tension plays an important part in fluidity one could expect that the running

*Libman gives these analytical figures for impurities, though the impurities were doubtless Fe, Al and Si introduced from the crucible through hydrogen reduction in the presence of molten copper. Since Fe_2O_3 and Al_2O_3 were not separately determined the data cannot be recalculated to the metals, but the probable impurities were 0.05% or less Fe + Al, 0.02% Si.



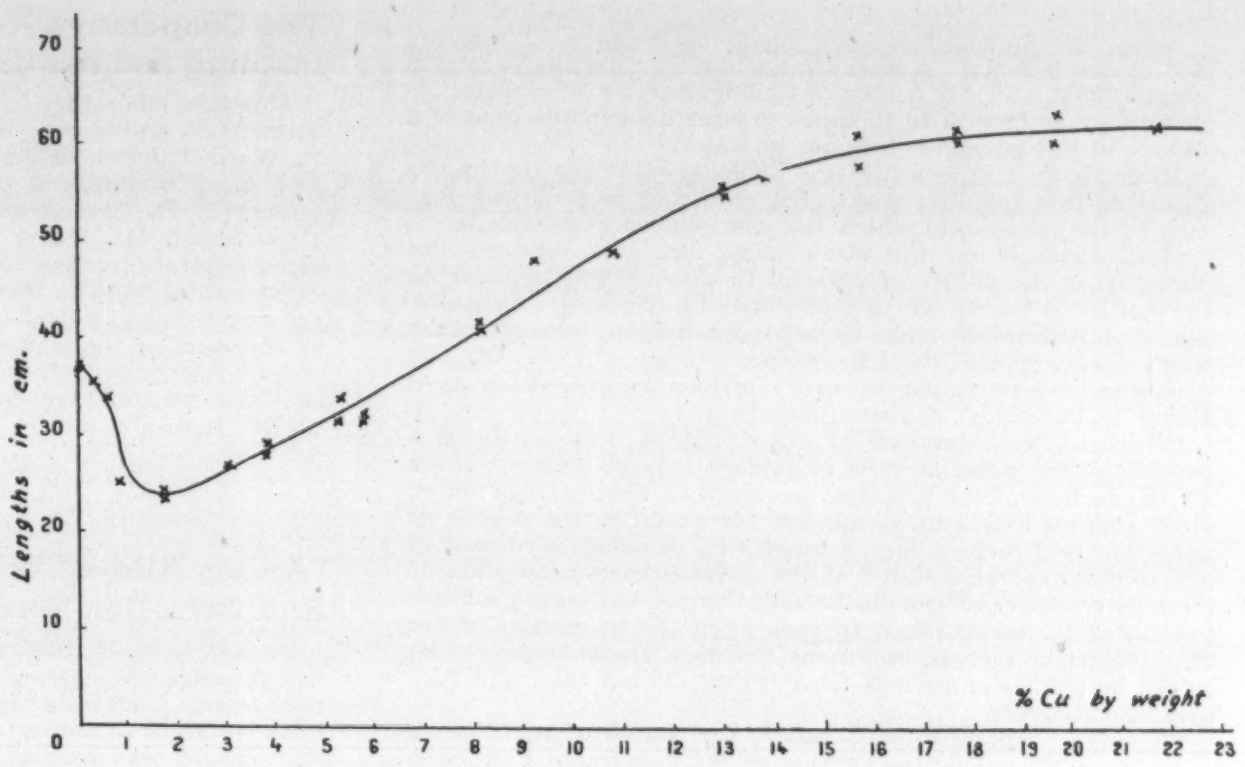


Fig. 11a. (at right) Running quality-concentration diagram of Al-Cu alloys.

Fig. 11b. (above) Left part of the equilibrium diagram of Al-cu alloys.

quality of tin bronze should increase with an increase in the Sn content. A certain proof of this is provided by some experimental data[10,11] indicating that the running quality of tin bronze is improved with an increase in the Sn content. It is to be much regretted that at the present time we do not have enough reliable data on the runability-concentration of molten metals determined by the same method and particularly on their surface tension. As long ago as 1914 Smith,[12] using a capillary depression method, determined the surface tension of some metals, among them Cu and Al. The mean value of the surface tension of Cu at 1150° C. was given by him as 1178 dynes/cm. and that of Al at 700°-820° C. as 520 dynes/cm. Smith used very narrow (1 mm.) carbon tubes. In his calculations he assumed that the angle between the normal to the free surface and the tangent to the liquid surface where it meets the solid walls approaches 180° and he used the values of liquid densities as given by Pascal and Jouniaux and by Roberts-Austen and Wrightson.

Although Smith's data are probably far from being exact, nevertheless work indicates that the surface tension of Cu is about twice as high as that of Al.

Using this as a base one would think that at least within the solid solution range the running quality of Al should be lowered when Cu is added.

Proof of this assumption appears in the left end of the runability-concentration diagram of Al-Cu alloys (Fig. 11A) given by Curty.[13] This part of the diagram shows a distinct drop in the running quality of Al-Cu alloy with an increase in Cu content up to about 1.5% Cu; further addition of Cu, however, causes a considerable increase of the running property of melt.

Present data are very meager and much more work needs to be done. If we knew, for instance, more about the surface tension of Ni we probably could explain the curious power of Ni to impart fluidity to the bronzes.

Although the addition of Ni raises the melting point of bronze and on this account might be expected to diminish the ease with which the molten alloy fills the mold, the reverse was found by Pilling and Kihlgren.[14]

Surface tension seems to be the governing factor in all processes of welding, soldering, and joining. It has been shown (A. W. Coffman, doctor's dissertation, 1927, Chemistry Department, University of Illinois)[2] that those fluxes that are most effective in soldering are just those whose presence causes a lowering of the surface tensions of the metals that become molten in the soldering operation.

In the application of surface tension data to practical cases the true surface tension between the liquid and its vapor does not always give a complete picture. Where the liquid wets a solid the interfacial tension between the liquid and solid also plays a part in the phenomena which occur.* We may, indeed, ascribe a surface tension to the solid itself. When the liquid and solid are mutually soluble, the resulting change in the surface tensions of the now impure substances further complicates the problem. It is evident that the lack of the necessary data, due to the difficulty of securing them makes the usefulness of theoretical considerations very slight in the particular case of soldering.

Bircumshaw[15] observed that a very long duration of heating in vacuum is necessary to expel the dissolved gas from a metal. In the case of Al it was observed that after 114 hours gas was still coming off. If we consider, as Bircumshaw says, the formation of spherical bubble of radius r in the interior of metal of density d at a depth of h cm. below the surface, then if T is the surface tension of the metal, a pressure $(\text{h.d.g.} + \frac{2T}{r})$ dynes/cm.² must be exceeded in the bubble before it can grow.

*See Freundlich, "Colloid & Capillary Chemistry," Hatfield's translation, from the 3rd German edition, page 157. E. T. Dutton & Co., New York, 1926.

Tapping 6-Ton Electric Furnace. (Courtesy Bethlehem Steel Co.)

When the bubbles are very small, the term $\frac{2T}{r}$ becomes considerable, and for a minute bubble forming in a metal its value may be from 5 to 10 times greater than in the case of a bubble of the same size forming in water.

Bircumshaw suggests that the difficulty of removing the gas dissolved in a metal is due to *the relatively high surface tension* of the medium in which the gas bubbles are formed.

McC. Lewis,[16] on the other hand, has put forward the theory that the ability of a metal to dissolve gas depends on the ability of a metal to dissociate it. Thus, as Hanson[17] stated, for removal of gas from a melt it is necessary to take into account both of these influences.

Surface tension must be given serious consideration as a factor in the study of molten metals.

Of course, consideration of the ability of a metal to fill a mold from the point of view of surface tension does not cover all the factors of the practical problem. In the case of iron or steel with an excess of aluminum, for example, the degree of oxidation is a factor, since a tough film of oxide is formed in air, so that the "runability" of the metal is more a question of its ability to break through the film than of the actual surface tension of the metal itself. In such cases the properties of the film are major factors, and many practical cases would not be solved by studies of surface tension that did not take such factors into account.

When this abstract was ready for publication, White's paper** on "The Surface Tension of Type-Metal Alloys" was brought to the attention of the writer.

It is interesting to note that one of the White's conclusions was that "The low surface tensions of the type-metal alloys play a very important part in their ability to reproduce faithfully the shape of the mold in which they are allowed to solidify. The effect of zinc, under oxidizing conditions, is a strong argument in favor of this conclusion, as it is definitely known from bitter experience, often repeated, that even the merest trace of zinc will render type metals totally unfit for casting type."

**H. Vance White. The surface tension of type-metal alloys. *Bulletin Virginia Polytechnic Institute, Engineering Experiment Station Series Bulletin* No. 13, January 1933.

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[15] L. L. Bircumshaw. The Solubility of Hydrogen in Tin and Aluminium at High Temperatures. *Philosophical Magazine*, Series 7, Vol. 1, 1926, pages 510-522.

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Consolidation

The C. Newman Wire Co., Inc. and its manufacturing affiliate, J. D. Crosby Co., have consolidated their interests, and their selling and manufacturing activities will be conducted under the name Newman-Crosby Steel Corporation.

The Cooperative X-Ray Laboratory of Mellon Institute and the University of Pittsburgh

This new laboratory is located in a small building adjoining Thaw Hall, and is supervised by a committee consisting of Dr. E. Ward Tillotson of Mellon Institute, Professors C. G. King and A. L. Robinson of the Chemistry Department, and Professors T. H. Osgood and Arthur E. Ruark of the Physics Department. Dr. Ruark is chairman of the committee, and gives general direction to all projects undertaken. The actual experimental work is being carried out by Dr. Victor Hicks, and by students, under his guidance. The laboratory is utilized by members of the staff and graduate students in the Physics and Chemistry departments. The services of the laboratory are available to, and are frequently used by, research men of Mellon Institute and by other departments of the university.

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"Amsco Alloys" For High Temperature And Corrosion Services

On February 15, 1933, a contract between **F. A. Fahrenwald** and **American Manganese Steel Co.** was terminated by mutual agreement. Under the agreement now existing, AMSCO retains the right to use certain patents issued and pending, while Fahrenwald was granted the exclusive use of the registered trade-name "Fahralloy," effective July 1, 1933. The nickel-chromium alloys made and sold by The American Manganese Steel Co., shall be known by the trade-name "AMSCO ALLOYS."

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A Campaign for New Uses for Steel

The Association of Iron & Steel Electrical Engineers, whose aims and objects are the advancement and development of all forms of engineering to the iron and steel industry, has completed a campaign which will promote new uses for steel.

The purpose of this campaign was to find new markets, new outlets, new applications for the use of steel.

Prizes will be awarded at the 29th Convention of the A. I. & S. E. E. in June, 1933.

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A. S. T. M. Exhibit to Feature Special Testing Apparatus

A number of the displays in the Second Exhibit of Testing Apparatus and Equipment, which the American Society for Testing Materials is holding at The Stevens, Chicago, June 26-30, will feature special testing equipment developed by research laboratories and the society committees. Manufacturers of testing and related equipment will sponsor displays which emphasize new apparatus, as well as improvements in the more standard types. In these booths will be found equipment for tests and studies of metals, cement and concrete, petroleum products and many other engineering materials as well as laboratory apparatus, recording apparatus and other scientific and technical instruments. Hardness testing equipment, laboratory glassware of all types, universal testing machines, balances, thermoregulators, fatigue testers, etc., will be shown.

A. S. T. M. committees which are planning to participate include A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys; B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys; C-1 on Cement; C-7 on Lime; and D-9 on Electrical Insulating Materials. There will be shown apparatus and a method for corrosion testing by means of the acid and salt spray solutions; a newly developed turbidimeter for determining the flow of cement and other fineness apparatus, and a set-up for testing the spreading of lime putty. There will be apparatus for determining properties of thermostatic metals under load and temperature, as well as a special oven and method for making short time s'udge tests of insulating mineral oils. University and other research laboratories will show equipment they have developed for making special tests and determinations.

Companies which will display equipment include:

Baldwin-Southwark Corp.	E. H. Sargent and Co.
Christian Becker, Inc.	Precision Scientific Co.
Central Scientific Co.	C.J. Tagliabue Mfg. Co.
Kimble Glass Co.	Wilson Mechanical Instrument Co.

Melting Points of Some Binary and Ternary Copper-rich Alloys Containing Phosphorus

By W. EARL LINDLIEF*

ONE of the metallurgist's most important tasks is the study of the constitution of alloy systems, for it enables him to prepare and treat alloys with intelligence and economy of effort and also to obtain the maximum benefits through treatment. These advantages are ordinarily the greater the more accurately the constitution is known. This work presents careful determinations on the melting curves and surfaces for alloys of copper and phosphorus and alloys of copper-silicon-phosphorus and of copper-zinc-phosphorus, a timely contribution in view of the recent interest in copper-base alloys containing phosphorus.

COPPER-PHOSPHORUS

GUILLET[1] gave a melting point curve of the copper-phosphorus system with a minimum of 612° C. at a composition of about 10% phosphorus. Hiorns[2] showed this minimum to be a eutectic and gave the temperature as 620° C. at 8.21% phosphorus. Heyn and Bauer[3] in 1907 gave the eutectic composition and temperature as 8.27% phosphorus and 707° C. respectively. In the 25 years which have elapsed since their paper no further thermal work has been published, although Huntington and Desch,[4] by microscopic examination and chemical analyses of slowly cooled alloys found the eutectic to contain 8.27% phosphorus.

Thermal Analysis

The present work was confined to a redetermination of the liquidus in the range up to 12% phosphorus and of the eutectic temperature and composition. The alloys were made from electrolytic copper and phosphor-copper of the following analysis:

Copper	85.22%	Lead	0.031%
Phosphorus	14.68%	Zinc	0.00 %
Tin	0.08%	Nickel	0.00 %
Iron	0.022%		

Seventeen alloys were made in 200 g. charges and cooling curves were taken using chromel-alumel thermocouples carefully calibrated against the following standard melting points:

Copper	1083.0°C.
Silver	960.5
Silver-Copper Eutectic	779.4
Aluminum	658.9

The alloys gave sharp arrests and no undercooling occurred either at the liquidus or at the point of eutectic solidification. The following table shows the intended and actual compositions of the alloys and the temperatures of the liquidus and eutectic arrests. (Table I) To avoid the difficulty of sampling the badly segregated alloys, the ingots were carefully remelted, stirred, and a small sample poured into water. The results are plotted in Fig. 1, which also provides comparison with Heyn and Bauer's work. The points do not lie on the curve as well as might be expected, but this

[1]L. Guillet. *Génie Civil*, Vol. 47, 1905, page 187.
[2]J. Hiorns. *Journal Society of Chemical Industry*, Vol. 25, 1906, page 616.
[3]Heyn & Bauer. *Zeitschrift für anorganische Chemie*, Vol. 52, 1907, page 129; *Metallurgie*, Vol. 4, 1907, pages 242, 257.
[4]Huntington & Desch. *Transactions Faraday Society*, Vol. 4, 1908, page 51.
*Copper Alloys Research Laboratory, The American Brass Co., Waterbury, Conn.

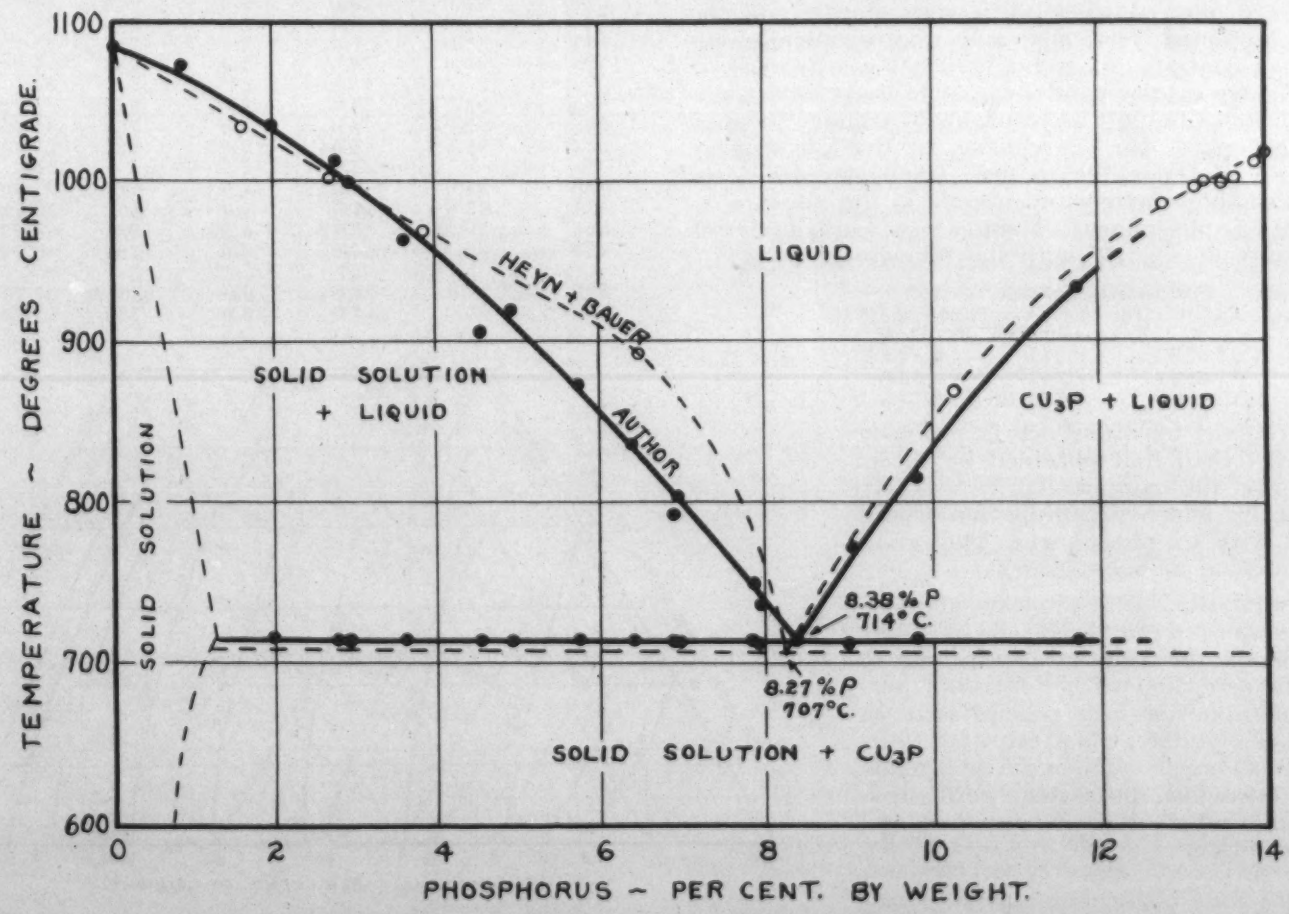
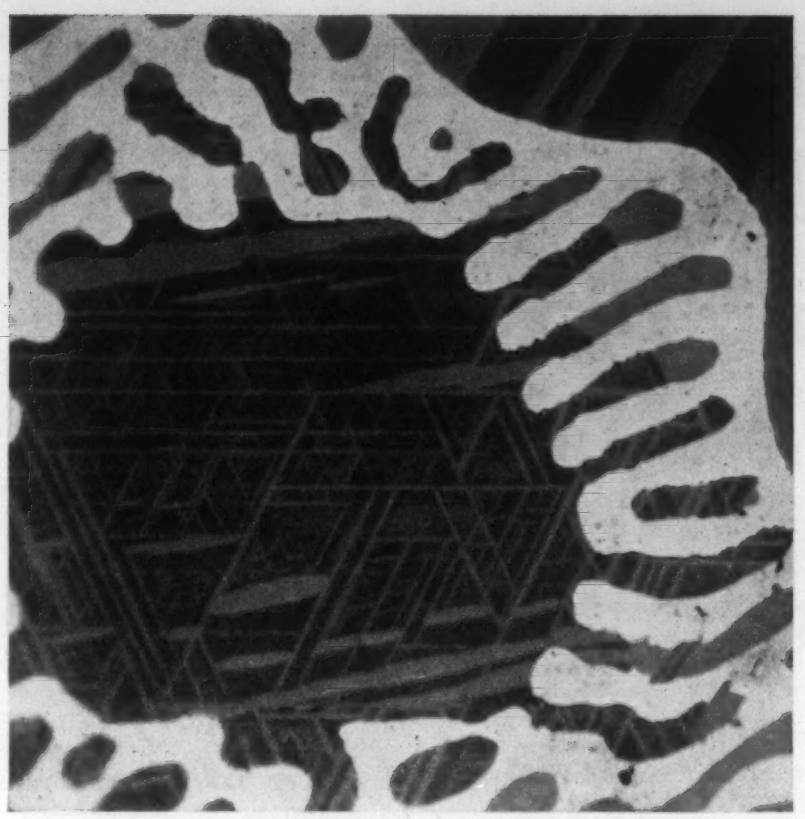


Fig. 1. The Equilibrium Diagram of the Copper Phosphorus System (0—14% P).



Cu 63.0 Zn 30.0 P 7.0
Zinc-rich phosphide + eutectic
Unetched. Mag. 1500×.

is undoubtedly due to the difficulty of sampling and chemical analysis. The solid solubility shown in Fig. 1 is that found by Hanson, Archbutt and Ford.[5] The cooling curves of the alloys containing 2, 4, and 10% phosphorus were taken down to 350°C. in the hope of determining some change in the compound Cu_3P coincident with its change of malleability at about 400°C. No alloy, however, showed any arrest below the eutectic point.

Eutectic Composition and Temperature

Of the 17 determinations of the eutectic temperature by thermal analysis, 8 were at 714°C., 4 at 713°C., and 5 at 715°C.; 714°C. may therefore be taken as the correct temperature. To determine the composition of the eutectic more accurately than could be done by thermal analysis, six 100 gram melts were made containing nominally 7.7, 7.9, 8.1, 8.3, 8.5 and 8.7% phosphorus. These were allowed to solidify very slowly and the ingots obtained sectioned vertically and microscopically examined. The alloys containing nominally 8.3% phosphorus or less contained primary copper dendrites, while those with nominally 8.5 and 8.7% phosphorus contained primary copper phosphide. On account of the segregation of the low density phosphide it was easily possible to drill small samples from selected areas consisting entirely of eutectic in the alloys containing 8.3 and 8.5% phosphorus. These areas were analyzed for both copper and phosphorus with the following results:

Alloy No.	Nominal Composition Phosphorus %	Composition of Eutectic Area Copper %	Phosphorus % By determination	Phosphorus % By difference
519	8.30	91.575	8.315	8.425
520	8.50	91.668	8.252	8.332
		Mean	8.283	8.378

The phosphorus content by difference is probably more nearly correct than that obtained by direct determination, since the copper figure was obtained electrolytically which determination would not be interfered with by phosphorus. This gives the eutectic composition of about 8.38%.

For the direct analytical determination of phosphorus, 1.0 g. samples were dissolved in nitric acid and portions of the solution equivalent to 0.1 g. taken. After oxidation with potassium permanganate the phosphorus was precipitated as ammonium phosphomolybdate, the precipitate thoroughly washed, dissolved in ammonium hydroxide and titrated with standard potassium permanganate after passing through a Jones reductor and into ferric alum solution.

[5]Hanson, Archbutt & Ford. *Journal Institute of Metals*, Vol. 43, 1930, page 41.

Pouring metal for strip metal bars. (Courtesy American Brass Co.)

Table I. Melting Points of Copper-Phosphorus Alloys.

Alloy No.	Composition—% Copper (Determined)	Phosphorus (By Difference)	Thermal Arrests Liquidus °C.	Eutectic °C.
411	99.12	0.88	1071	714
412	97.99	2.01	1034	715
413	97.19	2.81	1011	715
508	97.06	2.94	997	713
414	96.31	3.69	960	715
509	95.41	4.59	904	714
431	95.03	4.97	919	713
429	94.22	5.78	870	714
523	93.57	6.43	836	714
427	93.09	6.91	790	714
510	93.03	6.97	801	714
426	92.14	7.86	749	714
511	92.08	7.92	734	713
524	91.77	8.23	715	715
525	90.98	9.02	772	713
422	90.20	9.80	815	715
526	88.28	11.72	933	714

Table II. Melting Points of Copper-Silicon-Phosphorus Alloys.

Alloy No.	Composition—% Copper	Phosphorus	Silicon	Temperature of Arrests °C. Liquidus	Eutectic	Solid Transformation
536	94.0	5.0	1.0	880	724	—
537	93.0	6.0	1.0	821	727	—
538	92.04	6.96	1.0	763	728	—
539	91.0	8.0	1.0	756	726	—
527	96.0	2.0	2.0	969	737	—
528	94.0	4.0	2.0	905	737	—
540	93.0	5.0	2.0	836	733	—
541	91.0	7.0	2.0	744	732	—
529	90.0	8.0	2.0	884	720	701
542	93.0	4.0	3.0	842	731	—
543	92.0	5.0	3.0	783	735	—
544	91.09	6.04	2.97	732	732	—
530	94.0	2.0	4.0	917	737	—
531	92.0	4.0	4.0	805	738	—
545	90.93	5.12	3.95	731	731	—
419	90.0	6.0	4.0	784	731	—
532	91.0	2.0	6.0	801	733	680
533	90.0	4.0	6.0	780	743	693

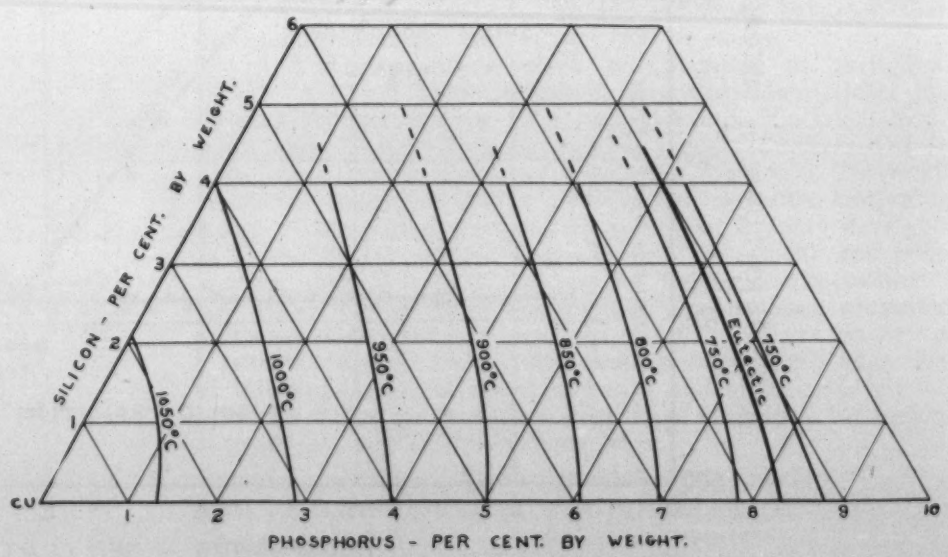


Fig. 2. Liquidus Isotherms of the Copper-Silicon-Phosphorus System.

Removing castings for strip metal from molds. (Courtesy American Brass Co.)

Table III. Melting Points of Copper-Zinc-Phosphorus Alloys.

Alloy No.	Composition—% Copper	Zinc	Phosphorus	Liquidus	Thermal Arrests °C. Binary & Ternary Eutectic	Solid Transformations	
447	85	10	5	839	727	—	
1086	83	10	7	742	735	—	
1087	82	10	8	768	729	—	
1088	80	10	10	856	727	—	
1089	73.2	20	6.8	718	711	—	
1107	69	25	6	711	702	—	
1108	68	25	7	721	695	611	
1109	67	25	8	750	694	594	
1090	66	27.5	6.5	697	—	603	
1061	68	30	2	877	701	—	
1062	67	30	3	824	694	682	
448	65	30	5	742	690	648	617
1077	64	30	6	697	—	595	
1063	63	30	7	714	696	690	
451	61.5	30	8.5	751	688	601	
1110	63.5	32.5	4	769	691	611	
1111	62.5	32.5	5	731	690	588	
1112	61.5	32.5	6	693	687	591	
1131	60.5	32.5	7	731	697 687	588	
1114	59.5	32.5	8	798	693 687	592	
1115	58.5	32.5	9	826	688	591	
1116	61	35	4	775	687	586	
1127	60	35	5	738	698 687	583	
1128	59	35	6	728	687	583	
1129	58	35	7	761	690	587	
1064	58	40	2	833	692	—	
1065	57	40	3	795	728 689	—	
1066	56	40	4	759	715 687	—	
1080	55	40	5	798	747 678	—	
1078	53	40	7	872	761	—	
452	51.5	40	8.5	867	735 691	599	
1067	49	50	1	855	742	—	
1068	48	50	2	809	772	—	
1069	47	50	3	—	775	—	
1081	46.5	50	3.5	795	750	—	
1079	46	50	4	820	776	—	
449	45	50	5	840	775	—	

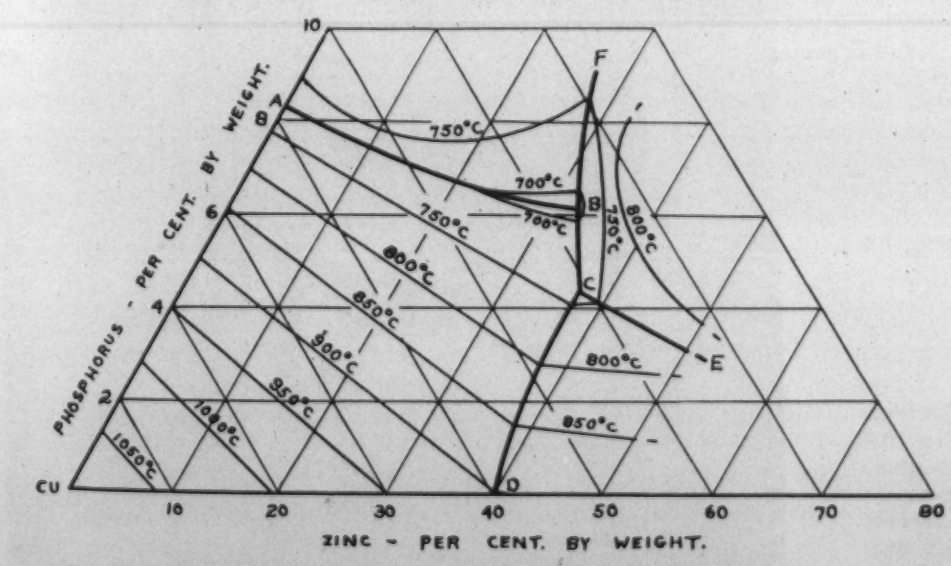
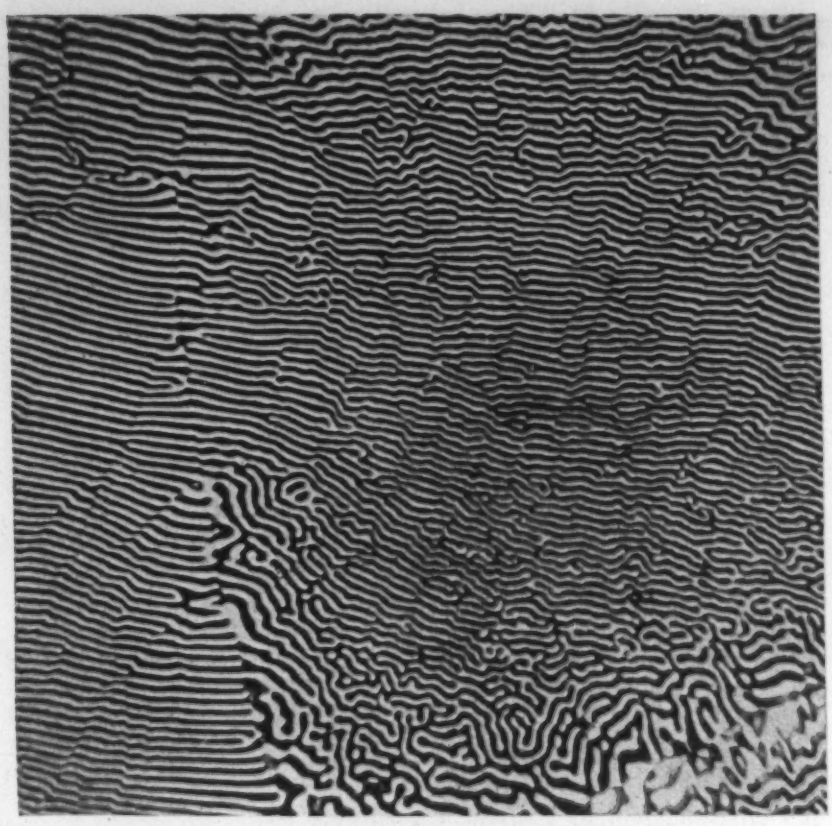


Fig. 3. The Liquidus of the Copper-Zinc-Phosphorus System.



Cu 91.09 P 6.04 Si 2.87
α-Cu_3P Eutectic
Etched with $K_2 Cr_2 O_7$ and $Fe Cl_3$. Mag. 1000×.

Comparison with Previous Work

On comparing the curve obtained by the present work with that of Heyn and Bauer, the liquidus is seen to be considerably lower, particularly at a composition of 6.5% phosphorus where there is a difference of about 50°C. Since Heyn and Bauer determined only one point between 4 and 8% phosphorus, while in the present work 8 alloys were investigated in the same range, it is more likely that the new curve is correct.

The eutectic temperature of 714°C. is 7° higher than that given by Heyn and Bauer and the phosphorus content is 0.11% greater.

COPPER-SILICON-PHOSPHORUS

The liquidus of part of the copper-silicon-phosphorus system was determined in a manner similar to that employed for the copper-phosphorus system. Cooling curves were taken on 18 alloys, the results of which are given in Table II. Liquidus isotherms are plotted in Fig. 2. The composition of 3 alloys analyzed showed a maximum difference of 0.13% from the intended composition of either silicon or phosphorus. The remainder of the alloys were not analyzed, the synthetic composition being given in the table.

As Fig. 2 shows the liquidus slopes uniformly downward from the melting points of the copper-silicon alloys as increasing amounts of phosphorus are added. A eutectic valley extends across the ternary diagram from the copper-phosphorus eutectic at 8.4% phosphorus, it consisting of a series of binary eutectics between the α solid solution of silicon and phosphorus in copper and the Cu_3P compound, the latter probably containing silicon in solution. The melting point of the copper phosphorus eutectic (714°C.) is raised by the addition of silicon, that containing 1% silicon melting at about 725°C.

COPPER-ZINC-PHOSPHORUS

Using the methods previously described the liquidus of that portion of the copper-zinc-phosphorus system containing up to about 50% zinc and 8% phosphorus was determined. In making the alloys zinc was added in the form of a Cu-Zn alloy containing 60% zinc except in the alloys with a phosphorus content of 7% or greater in the 32.5, 35, and 40% zinc series, and those containing 4 and 5% phosphorus in the 50% zinc series, also alloys 447, 448, and 451. The results of the thermal analysis are given in Table III, while Fig. 3 shows them diagrammatically. No attempt was made to analyze the cooling curve ingots. To obtain a representative

sample it would have been necessary to remelt the ingots which would have caused too great a loss of zinc by volatilization. The actual zinc content of the alloys is undoubtedly within ± 1.0% of that intended.

In the diagram, Fig. 3 the surface Cu-ABCD represents the solidification of primary solid solution of copper, zinc, and phosphorus. The addition of phosphorus lowers the melting points of the copper-zinc alloys and the liquidus slopes downward as the phosphorus content is increased. From the copper-phosphorus eutectic a binary eutectic extends across the ternary diagram, formed between the α solid solution and Cu_3P, the solidification of which is represented by the surface ABF. At an approximate composition of 32.5% zinc and 6% phosphorus, a ternary eutectic with a melting point of about 690°C. is formed. It consists of α, Cu_3P and a zinc rich phosphide of unknown composition, the latter represented in the area FCE.

The zinc rich phosphide has a high melting point as shown by the rapid rise of the liquidus in the section FCE. The surface DCE represents solidification of the β copper-zinc-phosphorus solid solution.

Summary

The liquidus of the copper-phosphorus system up to 12% phosphorus has been redetermined, and also the eutectic temperature and composition. The eutectic temperature was found to be 714°C. and the phosphorus content about 8.38%. The maximum difference between the new liquidus and that of Heyn and Bauer occurs at about 6.5% phosphorus where the present curve is about 50°C. lower. Tentative diagrams are given for the liquidus of parts of the copper-silicon-phosphorus and copper-zinc-phosphorus systems for copper rich alloys.

Acknowledgments

The author wishes to express his thanks to Dr. Cyril Stanley Smith, at whose suggestion and under whose supervision the work was carried out, and who offered many helpful suggestions in the preparation of the manuscript. Acknowledgment is also made to Mr. W. H. Bassett for his permission to publish the results.

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Tentative Standard Grain Size Chart

The new Tentative Standard Grain Size Chart for Classification of Steels (E 19-33T) was recently approved for publication as a tentative standard by the A.S.T.M. Standards Committee on the recommendation of Committee E-4 on metallography. Copies of this chart can be obtained from the American Society for Testing Materials, 1315 Spruce St., Philadelphia, Pa. The cost for single copies is 25 cents.

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American Stainless Files Appeal

The American Stainless Steel Company, of Pittsburgh, and the Electro Metallurgical Company, of New York, are filing an appeal with the United States Circuit Court of Appeals at Baltimore in their infringement suit against the Rustless Iron Corporation of America. The lower court recently held the Clement Patent on Stainless Iron under which the suit was brought to be invalid because of an earlier patent on similar material granted to Elwood Haynes. The Haynes Patent is also owned by the American Stainless Steel Company.

The Rustless Iron Corporation's process of manufacturing rustless iron was declared by the court to be "in all material respects a duplication" of that described by Hamilton & Evans in their process patent owned by the American Stainless Steel Company and which is the other patent in suit. However, the Hamilton & Evans Patent was held invalid because its essential features are said to be the same as those of an earlier patented process for producing ferro chromium. This portion of the lower court's opinion seems to affect adversely not only the process patent on which the suit was based but also the process being used by the Rustless Iron Corporation.

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Doehler Main Office Moved

Beginning June 1st the main executive office of the Doehler Die Casting Co. will be located in Toledo, Ohio, including the office of Mr. H. H. Doehler, Pres., and Mr. F. J. Koegler, V. P. and Treas. The New York Sales Office under the management of Mr. L. H. Pillion, Vice President, and Eastern Sales Manager, will be maintained at the old address of 386 Fourth Avenue, Rooms 1804 to 1806.

New All-Metal Transport Plane

By Robert Steele

The transition from wood and fabric to metals as materials for airplane construction is exemplified in the 1933 models of transport planes in the United States.

First of several new type, high speed, all-metal commercial planes to make their appearance this year is the low-wing, ten passenger, mail and express Boeing monoplane, sixty of which are going into service on the United Air Lines for new fast schedules on the New York-Chicago-Pacific Coast and other mail passenger airways of the company.

In the matter of speed this plane ranks as the world's fastest multi-motored transport, demonstrated by its reduction of air travel time from coast-to-coast to approximately 18 hours and the introduction of a 4½ hour schedule between Chicago and New York. It serves as a particularly good example of all-metal construction in transport aircraft manufacture.

All-metal construction was decided upon for reasons of economy and efficiency. Greater strength and great durability were offered in all-metal planes and these attributes were regarded highly by United Air Lines, whose coast-to-coast route traverses the country from the shores of California across lofty mountain ranges and various types of terrain to the sea level Newark Airport on New Jersey's marshes. On this route every type of weather is encountered, with temperatures ranging from 135° F. at certain points during the summer season to 45° below zero at points during winter weather.

United Air Lines felt that the substitution of the all-metal plane for the wood and fabric type would enable maintenance costs to be considerably reduced.

The chief material involved in the building of the Boeing Transport plane is the 17-ST alloy of the Aluminum Company of America, heat-treated (cold water quenched) and given the chromic acid anodic treatment.

Duralumin for the airplane skins, bulkheads and cowlings, is pressed into the desired shapes on a 700-ton hydraulic press. Virtually all parts are heat treated before going to the press since dural, unlike steel, hardens slowly after heat treatment and can be worked while aging.

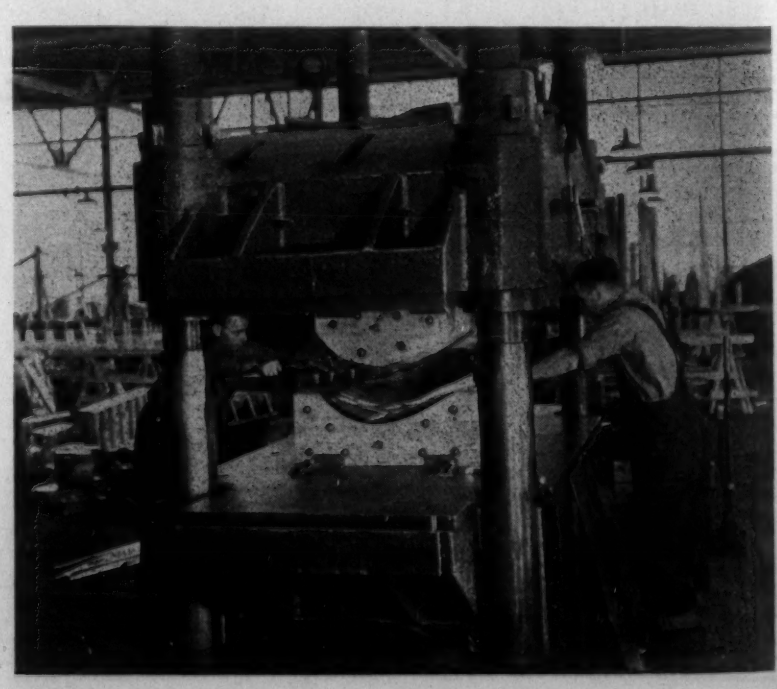
With a high speed of 190 miles per hour and a cruising speed of 170 miles an hour, the new-type passenger-cargo monoplanes mark a radically forward step in the development of commercial aircraft for the nation's airways.

The transport carries ten passengers, a crew of three and a cargo of mail, baggage and express. Fully streamlined, it has retractable landing gear to further boost its speed and is equipped with two 550-horsepower super-charged Pratt & Whitney Wasp engines.

While having a top speed of 190 miles an hour at an altitude of 5,000 feet, fully loaded, it lands at only 58 miles an hour. Despite the fact that it has a gross weight of 12,650 pounds, it takes off in a run of only 770 feet, climbs from sea level at the rate of 830 feet per minute, and reaches an altitide of 8,000 feet in only ten minutes.

The cruising range of the plane is 600 miles; the service ceiling 18,400 feet; and the absolute ceiling, 20,500 feet.

It is not for speed alone that the Boeing Transport claims attention as a new commercial aircraft development. With its high performance, it has the characteristics of exceptional strength, large pay-load, passenger comfort and operating economy. To these, the all-metal construction contributes.



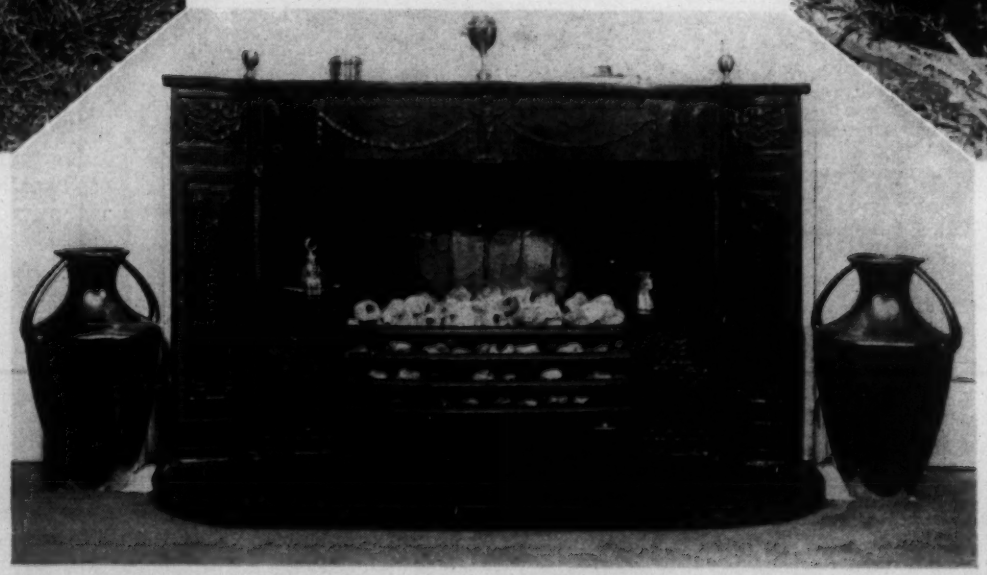
The BASSENHEIM Furnace

By H. E. WHITE*

IN the latter part of the 18th and early part of the 19th century, iron making was beginning to obtain a foothold in Western Pennsylvania. It was carried on in a crude way. The process was to burn the ore and then pulverize it by stamping very fine. Then it was placed in an open fire, 18 inches square by 15 inches deep, formed of stone, having a tuyere 5 inches below the top, one inch in diameter, supplied by blast from tubs, and water-wheel to drive the tubs, making a half pound to the inch; fuel, charcoal. Work commenced by filling the open fire with charcoal, when lighted up fully applying the blast in the tuyere; then adding the pulverized ore with a shovel by putting it on slowly above the blast, and as it melted the iron ran down below the blast, the cinder being drawn off, and when the space below the blast was filled up to the tuyere, being in a solid mass, it was raised out by a bar and taken to a hammer weighing 500 lbs., driven by a water-wheel at the rate of from 50 to 200 strokes per minute. The chunk was hammered into a bloom; then one end was heated in the same fire to a welding heat, and drawn into what was called an anchony. When some 20 or 30 of these were made, they then enlarged the fire to 20 inches square and 20 inches deep, and heated the bloom or large end, and drew it out under the hammer into bars of various lengths, from 5 to 10 feet long, and various widths and thicknesses, ready for market.

This process made a wrought iron. Later blast furnaces sprang up, being crudely constructed of silica rock with crude bellows or wooden air pumps called tubs driven by water wheels and using charcoal for fuel.

Ruins of Bassenheim Furnace between creek and road on Hereford farm . . . Only known castings of Bassenheim Furnace.



The iron industry of Pittsburgh, the most important iron center in the country, did not have an existence in the 18th century, although a blast furnace was built in what is now Shadyside in 1792 and abandoned in 1794. Ore was brought from a deposit of iron ore on Roaringrun, an affluent of the Kiskiminetas in the southeastern corner of Armstrong County by boat and some by wagon from the vicinity of Fort Ligonier and Laughlinstown in Westmoreland County. The expense entailed in bringing ore from localities so difficult of access in those days was too great to justify the continued working of the furnace. In 1794 the fire of the furnace lighted up the camp of the Whisky Insurrection. The American Iron Industry was gradually pushing westward as though attracted by some sort of magnetism to those great Lake Superior deposits. This trek followed closely on the heels of civilization. Two furnaces were in the vanguard and were the farthest west of their time. The one was built at Beaver Falls on the west side of Beaver River, in Beaver County in 1802 by Hoopes, Townsend & Co. and blown in in 1804. The whole enterprise was abandoned in 1826.

The other of these outposts of the Iron Age was the Bassenheim furnace built and put into operation by Dr. Dettmar Basse in the year 1814. He carried it on to 1818, when he sold out to Daniel Beltzhoover, who worked it 5 or 6 years more. About that time, viz., 1824, the charcoal and iron ore beginning to fail in the neighborhood, and his capital being pretty much sunk, he ceased operations and retired leaving the furnace a ruin, and now there is nothing to mark the place of its location except a large stack of stone overgrown with moss and bushes, and also a great pile of cinders, clinkers, and ashes, to show where the furnace had been. This furnace was not located in

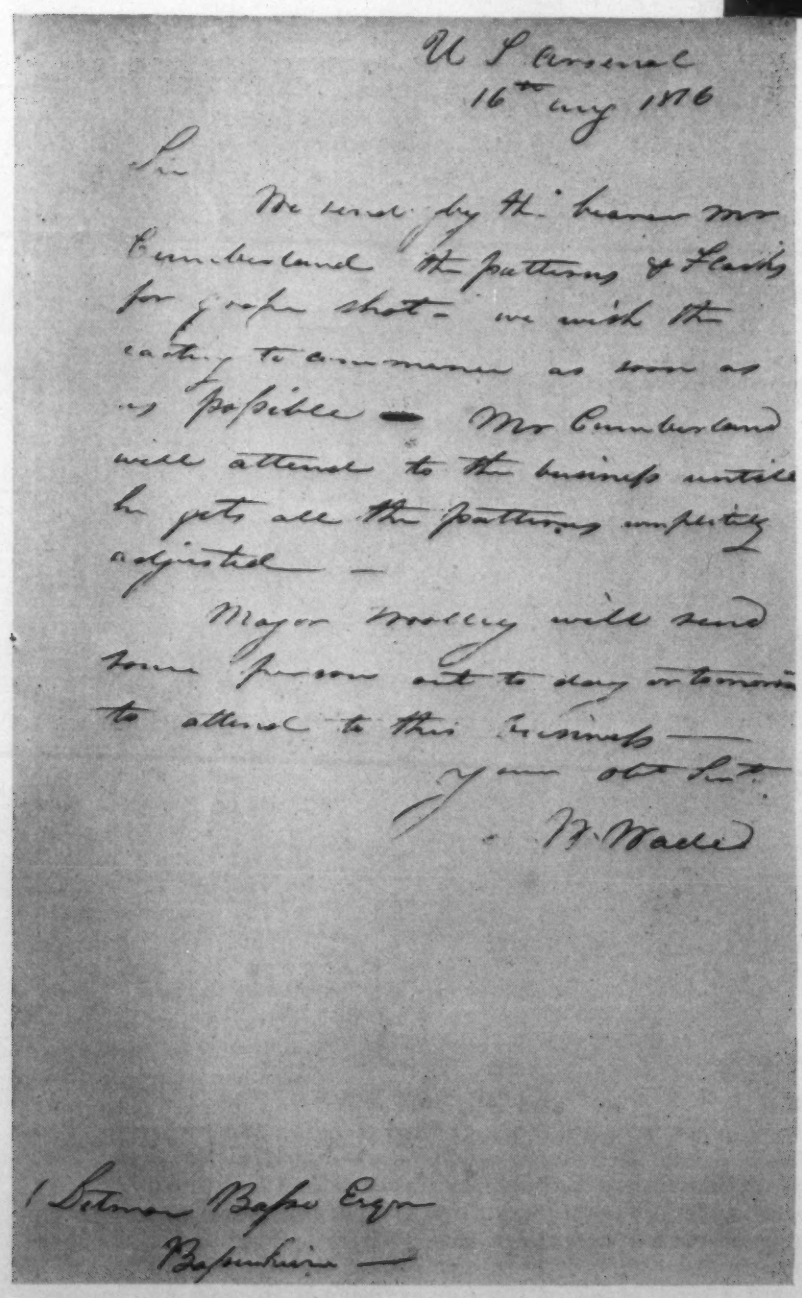
*Ceramic Engineer, Lava Crucible Co. of Pittsburgh.

Butler County, but in the adjoining county of Beaver, between 2 and 3 miles from Zelienople and lower down the Connoquenessing Creek and about a mile west of the Butler County line. Its owners, Dettmar Basse and also Daniel Beltzhoover, resided at Bassenheim farm on the Butler side of the county line, and much of its business was transacted at Zelienople. These circumstances will account for the popular belief that this furnace was located in Butler County. There was no forge connected with it, nor any other work except to convert iron ore into pig metal, stoves, kettles, pots, fire iron, etc. The ore was mostly dug out of the ground within a mile or two of the furnace in lumps weighing from one pound to 50, generally of a blue color. At first the bellows was blown by water-power, but, after the high water of the creek had washed away one of the abutments of the dam and let the water out, the owners were obliged to apply a steam-engine at considerable expense, by which it was afterwards operated with much trouble and little profit. After the war of 1812 times were very hard and money exceedingly scarce. One other reason that this work did not succeed and pay better was the great expense of getting its metal and wares to a market. In February 1818, $12 per ton was paid for hauling the pig metal to Pittsburgh, 30 miles, over a bad road. John Henry Hopkins, afterwards Bishop of Vermont, was engaged as manager at Bassenheim furnace about 1815.

Many interesting tales are told concerning Bassenheim furnace and its eccentric owner. Dr. Basse was a learned and scholarly man and as is frequently the case, was not a business man. Many of his dreams were fantastic. He saw a valley of thriving industry where the peaceful Connoquenessing flows through fertile farm acres. His dreams were of founding an industrial dynasty of considerable diversity. Fortunately for his daughter Zelie, her husband, Phillipe Louis Passavant was of a more practical mind.

Dr. Basse built a home on one of the hills near the furnace and called it "Bassenheim." This building resembled somewhat a baronial castle. Shortly afterward another wealthy settler, Dr. Müller, built a large home on an adjoining hill. These 2 gentlemen became good friends and frequently corresponded across the valley by the use of large blackboards, chalk and field telescopes. Some of the older residents tell of a large grindstone that was run in conjunction with the furnace. This was supposed to be some 3 feet in diameter. It and a large iron kettle are said to have been thrown down a large well near the furnace when the furnace was abandoned. The furnace proper was constructed on a hillside so as to facilitate charging, which was done by bridging across from the hill to the top of the furnace. The hearth was built of silica rock, a local quartzite. The furnace operated on a red kidney ore which was found in small pockets in the vicinity. Some of this ore can still be found and if washed and concentrated must have been fairly rich. Most of this ore was taken from localities on what is now the Ball Farm, but pockets are frequent in the vicinity of Zelienople. Charcoal to furnish the fuel and reducing medium was burned in the surrounding forest. The farms for miles around show frequent evidence of charcoal fires.

DETTMAR BASSE
From an old oil painting on wood.



U S Arsenal
16th Aug 1816

Sir

We send by the bearer Mr Cumberland the patterns & flasks for grape shot — we wish the casting to commence as soon as as possible — Mr Cumberland will attend to the business untill he gets all the patterns completely adjusted —

Major Woolley will send some person out to day or tomorrow to attend to this business —

Your obt Servt.
W. Wade

Dettmar Basse Esqr
Bassenheim —

Letter from U. S. Arsenal, 1816, arranging for casting of grape shot at Bassenheim Furnace.

Limestone was taken from a ledge about a mile due north of the furnace. With the combination of ore, charcoal, limestone and water power, together with a ready market, is it any wonder that Dr. Basse had visions?

As near as can be ascertained, the furnace was of about 5 tons capacity. That is, the bosh held 5 tons of ore. The operation was quite intermittent, depending upon the supply of raw materials, the demand for product, and the state of mind and cash position of the owner.

There is sufficient proof that pig iron was produced and at one time in fair quantity. There is also evidence that shot was made for the United States government. The most paying business was, however, in pots, kettles and miscellaneous castings that could be used by the surrounding settlers. However, the demand for these was soon satisfied and then the problem of transportation entered in which spelled the death of the enterprise. There is no evidence to confirm the statement that a cupola or iron foundry was run in conjunction with the furnace. On the other hand, those castings which are now in existence are too fine to have been cast directly from the blast furnace even with charcoal iron. What is more likely is that pig iron was first made and after the run when the furnace was hot, the gates, runners, and sufficient pig were recharged and the furnace run as a simple cupola. The castings must of course, have been run direct as there were no ladles nor ladle handling devices in use in this locality at that time.

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Charles Pack and **Louis H. Morin** have established consulting offices under the firm name of Pack-Morin, Inc., at 261 Fifth Ave., New York City, where they will offer a complete engineering service.

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James Kniveton, formerly in charge of electric heat treating furnace design with Ryan Scully & Company has joined the staff of the Ajax Electric Company, Philadelphia.